# Services and Air Conditioning for Tall Buildings*

by

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## INTRODUCTION

For the purposes of this paper it is proposed to define a ' Tall Building ' as one of 20 storeys or more, i.e. upwards of 200 feet high.

The maximum height of buildings in this country before the last war was as a rule about 100 to 120 ft. The reasons for the recent fashion to build sky-wards are not the concern of this paper, but it is becoming apparent that more and more tall blocks will be erected in densely built-up city areas, hence the considerable interest now being shown by engineers in the particular problems involved.

Experience of tall buildings abroad is readily available, and later in this paper it is intended to note some of the methods which have been evolved in other countries. But conditions may be very different from those obtaining in the British Isles and it is necessary to consider first principles particularly in so far as heating, ventilation and air conditioning are concerned.

Other services to which reference will be made chiefly with the object of discussing any differences from normal practice brought about by unusual height are : water supplies, sanitation, electrical services and lifts.

## HEATING, VENTILATION, AIR CONDITIONING

### 1. Low Blocks and Tall Blocks

Buildings of conventional heights, as normally planned, generally shelter one another to a greater or lesser extent, both from the sun and wind.

The tall block receives no such shelter. Planning requirements dictate that only a certain proportion of site area may be designed in a vertical manner, and furthermore some pattern of tall blocks is supposed to exist so that they shall not come closely together in groups.

It is thus inevitable that the tall block must be completely exposed on all sides to sun, wind, and the other elements, without any shelter or shading from other buildings with the possible exception of the lower storeys.

### 2. Sun and Orientation of Building

The motion of the sun from rising to setting subjects a building to a heating effect which is constantly changing throughout the day both in direction and intensity.

Figure 1 is a diagram of sun azimuths and altitudes for latitude 50°N. The paths of the sun for the summer and winter solstices, June 21st, December 21st, and for the equinoxes, March 22nd and September 22nd, are represented by the three lines drawn.

A surface normal to sun at this latitude at sea level (or up to 1,000 ft. above) will receive 278 B.T.U. per sq. ft. of solar radiation with a clear sky, intensities on surfaces at other angles being proportional to the cosine of angle of incidence. From the above data it is possible to calculate the amount of solar energy received on any surface at different times of the day and at different seasons.

It is perhaps interesting to consider the effect of orientation on the amount of solar energy which a building receives. For this purpose it is proposed to compare two cases as represented in Fig. 2.

The building in each case is assumed to have solid end walls and the two main elevations glazed.

In case I, the main axis is E-W, and the two principal faces are N. and S.

In case II, the main axis is N-S and the two principal faces E. and W.

Diagrams 3a and 3b are curves showing the variation in solar intensity on the S, E and W faces for June, and March or September respectively. These curves are based on the data referred to above.

From Figs. 3a and 3b it is possible to draw certain conclusions as follows :—

(a) For the orientation represented in Fig. 2 Case I (i.e. E-W orientation) the S face of the building receives less radiation in June than in September due to lower sun angle in the latter case.

(b) The greatest radiation intensity is felt by the E and W faces of a building orientated as in Case II (i.e. N-S orientation) in June, but in March and September it is still greater than South face in June.

(c) From a summation of the areas under the curves it is possible to compare the total solar heat falling on to the faces of the building for the two examples considered, assuming the sun to be shining consistently throughout a day. The North face is assumed to be in shade.

It will be noted that for June

Case I—orientation E and W

total incident radiation on S face = 802 B.T.U. per sq. ft/day

Case II—orientation N and S

total incident radiation on E and W faces = 1946 B.T.U. per sq. ft/day

i.e. nearly 2½ times the former.

Whereas for March and September the figures are

Case I—1409

Case II—1396

i.e. about equal.

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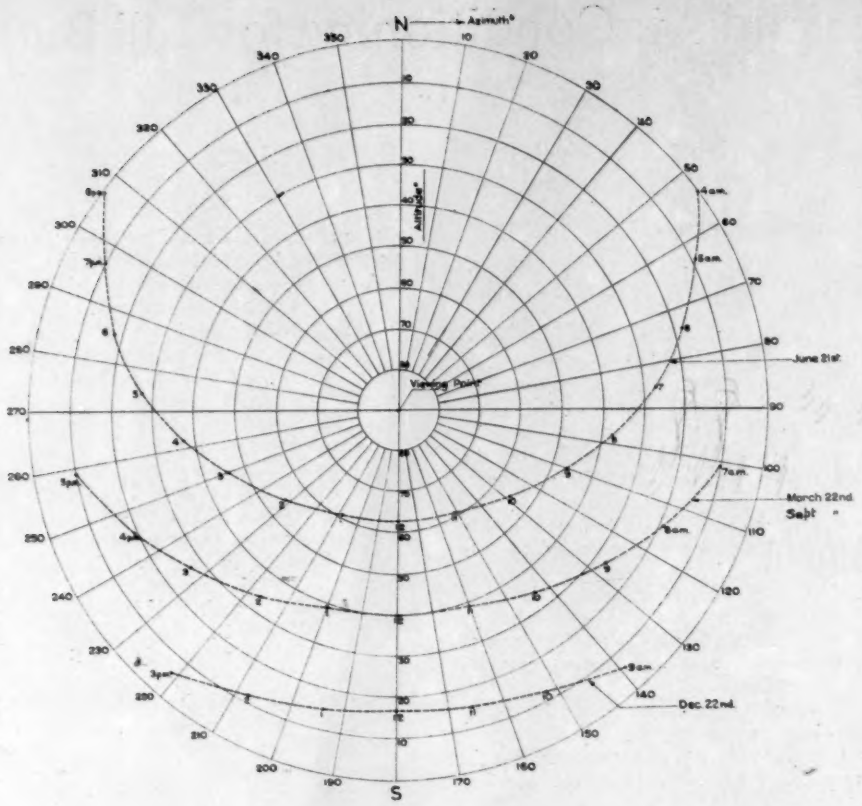


**Fig. 1.—Diagram of sun positions at 50° north latitude**

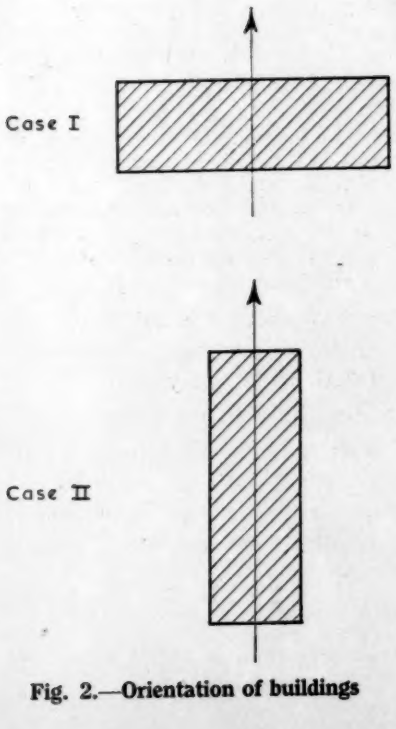


**Fig. 2.—Orientation of buildings**

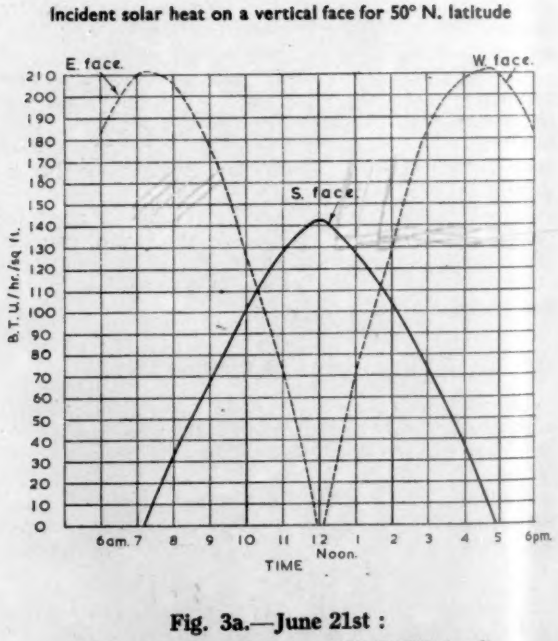


**Fig. 3a.—June 21st :**
**S. face—area under curve 802 B.T.U./sq.ft.**
**E. and W. faces—area under curve 1946 B.T.U./sq.ft.**

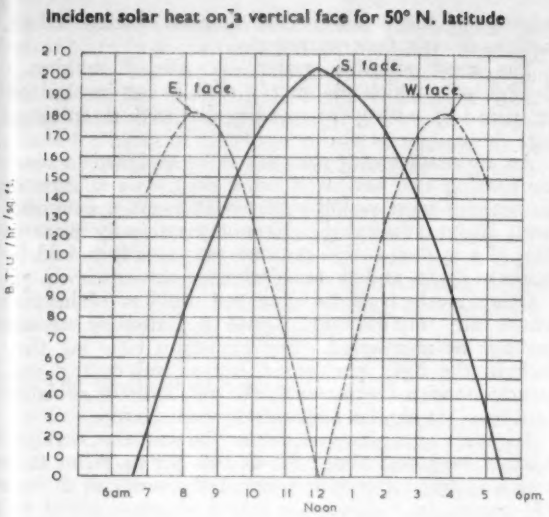


**Fig. 3b.—March 22nd and Sept. 22nd :**
**S. face—area under curve 1409 B.T.U./sq.ft.**
**E. and W. faces—area under curve 1396 B.T.U./sq.ft.**

(d) If the June difference is applied to a building 200 ft. high × 150 ft. long with long elevations ⅜ glass, assuming that 50% solar radiation passes into the building through shading, then heat entering = (1946-802) × ⅜ × 200 × 150 = 11,440,000 B.T.U/day approximately equal to 40 tons of ice per day.

(e) The difference in terms of simultaneous refrigeration load on the building is equal to about 50 tons of refrigeration or roughly 50 h.p.

From the air conditioning point of view it is therefore preferable to adopt the E-W orientation of Fig. 2 Case I on account of the saving, both in running cost and capital cost. There is, furthermore, no problem of intensive solar gain shifting from one side of the building to the other as occurs in Case II and calling as it does for considerable demands on the control system.

Whether or not from other points of view it is desirable to plan a building with one side facing North with no chance of sun entering—except in early morning and late evening around mid-summer—is another matter.

As a corollary, what is the effect of expansion on the structure of a tall building acting on one side and not on the other ?

## 3. Glass

Glass transmits solar radiation freely and instantaneously and, as large window areas are a feature of modern buildings, the principal source of heat gain in a tall building is usually the glazing.

Glass has the property of diathermancy whereby high temperature radiation from the sun is transmitted through it but low temperature radiation from within the building is not. Hence the well-known ' green-house effect.'

Solar radiation can be intercepted most effectively by provision of external shades or sunbreaks which in the case of buildings in the tropics often form the basis for interesting architectural treatment and perhaps no little difficulty for the Structural Engineer. Sun breaks call for separate consideration on the different aspects of the building and careful study is necessary to devise a complete solution.

In this country, however, provisions of this kind are hardly practicable and recourse must be had to internal shades, such as venetian blinds which, whilst intercepting glare and direct heat rays, only serve to change the form of the latter largely to convection within the rooms. Venetian blinds in the interspace between double glazing are a compromise often adopted.

If an unshaded window transmits 100%, shades will be effective to a varying degree according to type and colour, the proportion of heat still passing being

External shades 15 to 35%
Internal shades 60 to 75%
Venetian blinds in the interspace of double glazing 40 to 50%

## 4. Walls and Insulation

Any wall material will absorb solar radiation, thus becoming warm, and will re-transmit heat to the inside with a delayed action effect. The time lag depends on the mass, specific heat and insulation value of the material.

The tendency in modern high buildings is to use curtain walling or cladding in some form, of extremely light weight so that from a Structural Engineer's point of view minimum load has to be carried. This reacts unfortunately for the Services Engineer in affording minimum time lag effect and hence, apart from solar gains through windows, similar and almost instantaneous gains through walls have to be taken into account. In the case of more solid constructions of brick or stone the time lag is so great that this factor is frequently ignored.

Apart from direct solar radiation, a building is subjected to scatter radiation from sky and ground.

## 5. Effect of Solar Radiation

To summarise :—

(a) The effect of solar radiation is much more important in the case of a tall building than in a low one where some degree of shading from surrounding buildings usually exists.

(b) Maximum intensity will occur on one face in the morning and will shift round as the day advances so subjecting different aspects to widely varying heat gains.

(c) From an air conditioning point of view minimum heat gain is achieved with a building whose main axis lies East and West.

(d) The large expanses of glass, and light forms of wall construction usually adopted for tall buildings do nothing to help the problem of solar heat gains, but quite the reverse, they accentuate them and render thermal lag at a minimum.

## 6. Internal Heat Gains

The tendency nowadays is towards mechanisation for book-keeping, accountancy, the keeping of statistical records, calculation of wages and so on. Electronic computers are also being increasingly employed to aid in market research, in directing production and other similar capacities. The future of automation appears to be limitless.

All apparatus of this kind being electrically operated emits heat which, whilst helping to warm the building in winter, is unwanted in summer and adds to the solar gains already referred to.

Furthermore, although the tall building should have all the daylight it needs, it is frequently found in practice that shades are drawn to keep out the glare and artificial light is kept on during day-time. Lighting intensities have risen considerably over the past 10 or 20 years and are still on the increase, 3 watts per sq. ft. being common, rising to 7 or 8 in some cases. Electrical energy consumed in lighting is almost entirely dissipated as heat within the building.

Apart from the above, there is also heat from occupants equivalent to about 100 watts per person of sensible heat plus latent heat in the form of evaporation from the skin and moisture in the exhaled breath.

### 7. The Cooling Problem

The above description, as will be seen, is qualitative not quantitative. Ample data exist in the I.H.V.E. Guide[1], the American Society Guide[2] and in numerous textbooks and this would not appear to be an appropriate place to single out examples which might only be misleading.

In general terms, however, it may be said that the first problem presented to the Services Engineer by the tall building is that of cooling. Certain rooms or aspects may be heated by sun and internal gains whereas other rooms may be cold and need warming and, as the day advances, the conditions may change from one office to another or from one side of the building to the other with great rapidity.

### 8. The Opening of Windows

The great majority of conventional office buildings have relied in the past on the opening of windows to deal with these changing effects of climate or other heat sources. If the room gets stuffy the window is opened. If too cold it is closed.

In the tall block, however, the opening of windows is unsatisfactory owing to the greater wind pressures existing at heights well above ground. Structural engineers will know the kind of allowances which have to be made for these high structures. If a window is opened in a block, say 200 ft. above ground, on the windward side undue air motion is caused and papers are blown about. Any attempt to throttle the aperture by adjusting the opening to a minimum may cause a whistle to be set up. E. Harrison[3], has drawn attention to the effect of height of building on air-change rates.

In large office spaces the opening of windows only causes draughts to those nearby, with doubtful benefit to others more remote. Dirt and dust in the atmosphere carried in from outside in this manner can be a nuisance as well as calling for frequent redecoration.

Thus, although it may appear paradoxical, the tall building cannot be expected to rely solely on natural ventilation if satisfactory conditions for the inhabitants are to be provided. Hence, many such blocks in this country are being equipped with full air conditioning from the outset and this appears to be the only real answer to the problem.

Before considering method it is necessary to touch on the question of heating.

### 9. Heating

In a building of light, as opposed to massive, construction, the thermal time lag is short as has been pointed out. Internal heat gains and solar gains even in winter may often cause a rapid rise in temperature, falling equally rapidly when these influences are removed.

The system of heating must therefore be very responsive. The most unsuitable system would be one relying on the structure for thermal storage effect, such as electric floor warming.

The most suitable system is one of maximum flexibility in which the supply of heat can be shut off or turned on with great rapidity and with no inherent lag.

An air conditioning system can be designed to serve for heating also and as it relies on the circulation of air without massive hot surfaces, it meets the requirement above admirably. Economy normally dictates that if a system can serve two purposes it should be made to do so, and this is obvious in this case.

Other methods of tackling the problem of heating where air conditioning cannot be afforded should perhaps be mentioned. For minimum time lag they include the light perforated heated sub-ceiling constructions with thermostatic control, and the so-called ' sill line ' or similar underwindow convectors.

In terms of capital cost it may be said that straight heating may cost about 5/- to 10/- per sq. ft. of floor area and full air conditioning of the order of 20/- to 25/- per sq. ft.

### 10. Air Conditioning in General

Air conditioning performs the function of :—

(a) Ventilation with filtered air
(b) Cooling when required
(c) Heating when required
(d) De-humidifying or humidifying.

Dealing with these in turn :—

(a) Ventilation is provided by the drawing in to the plant room of fresh air, which is filtered in one or more of the various forms of high efficiency filter, thence being delivered through a series of ducts throughout the inhabited spaces. This same air is then exhausted, often via the toilets, and is discharged back to atmosphere.

(b) Cooling is provided by refrigerating plant and the same ventilation air may be used as the vehicle, or the cooling may be distributed as chilled water in a manner to be described.

(c) Heating similarly may use the ventilation air as the vehicle, or hot water may be circulated throughout the building. In either case the heat will most probably be generated in boiler plant, probably burning oil fuel. In order to save the construction of a flue throughout a tall block, there is a good case for placing the boiler-house on the roof.

(d) De-humidifying is performed by passing the ventilation air over chilled coils or through chilled water sprays whereby its temperature is brought down below the ambient dewpoint and condensation of moisture from the atmosphere then occurs. It would leave the plant at a lower controlled dew point to give the correct relative humidity in the building. De-humidifying is normally required in hot summer weather.

Humidifying is effected by passing the ventilation air through warm water sprays, or by adding water vapour or spray direct in some form and is normally required in this country only in cold weather.

### 11. Air Conditioning for Tall Buildings

Systems particularly suitable for tall buildings have been developed following two main principles :—

(a) The single duct system with water circulation throughout the building.

(b) The double duct or ' all air ' system where cooled and warmed air is circulated throughout.

As the chief source of heat gain is the window, the logical place to apply cooling is at this point. Similarly the window has the greatest heat loss in winter and heating applied below the window counteracts down draughts. In both systems the space below the window is used for input of air either cooled or warmed as the case may be. They are thus described as 'perimeter systems.'

Both make use of the high velocity technique of air distribution so that comparatively small ducts may be used operating at 3,000 to 4,000 ft. per minute. Fan pressures are much higher than normal, of the order of 5-6 in. s.g., and hence sound attenuators or silencers are necessary after the fan.

## 12. The Single Duct System

In this system the quantity of air distributed is a minimum to meet the needs of ventilation. The fresh air is conditioned in air handling plant or plants located either in the basement, on the roof, or at intermediate floor levels, separate plants sometimes being allocated to different zones or aspects of the building.

The conditioned or 'primary' air is delivered in ducts generally run vertically on the lines of the columns, and serving at each floor an 'induction unit' below each window or module.

Parallel with these ducts, and sometimes on alternate columns, insulated water circulating piping is carried and likewise connected to each induction unit.

The unit consists of a silencing chamber from which the 'primary' air issues through a series of jets so arranged as to cause an induction effect. The induced 'secondary' air from the room is caused to be drawn over the finned coil contained within the unit and through which the cool or warm water is circulated.

The induction ratio is usually about 2 of recirculated air from the room to 1 of primary air. Thus, if the primary or ventilation air is at the rate of 2 changes per hour, the total air in motion in the space will be equivalent to 6 changes per hour. Thus, a brisk circulation is set up. Individual or group thermostatic control is usually applied to vary the water quantity passing through the coil, although in one form control is effected by diverting the air either through or by-passing the coil.

The two types of unit are shown diagrammatically in Figs. 4 and 5.

In summer the air supply is warm and chilled water circulates in the coil; thus, if a room is too cool, the cooling is cut off and the air supply serves to raise temperature.

In winter the air supply is cool and warm water circulates in the coil.

Where means of control is by varying water quantity it is obvious that two cycles are involved, one where increasing water flow is required to lower temperature, and one where increasing flow is required to raise temperature. This requires some means of change-over of thermostat operation according to whether winter or summer cycle is required. There are various ingenious methods for carrying out this function. In one system a third pipe is employed to enable units to be cooling or warming at will.

In a typical bay 10 ft. wide × 20 ft. deep × 10 ft. high, the primary air supply might be about 70 cu.ft/min. and the cooling load about 8,000 B.T.U./hr. equivalent to $\frac{2}{3}$ ton refrigeration. If the building contained 20 floors each with 40 such units—800 in all—total primary air = 56,000 cu. ft/min. and total connected refrigeration load 530 tons. The maximum co-incident load would be less than this, say of the order of 400 tons, and the compressor horse-power would be about 450 b.h.p.

Ducts may be run vertically to serve any number of floors, but within convenient dimensions about 10 is usual, thus a 20 storey building could as in Fig. 6 be served from plant rooms top and bottom, or from one plant room midway serving up and down, Fig. 7.

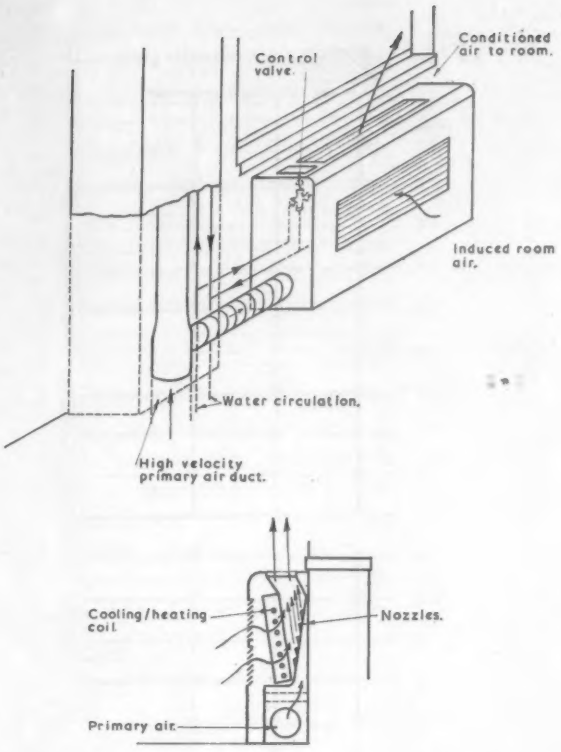


**Fig. 4.—Coil type induction unit with control by water flow regulation**

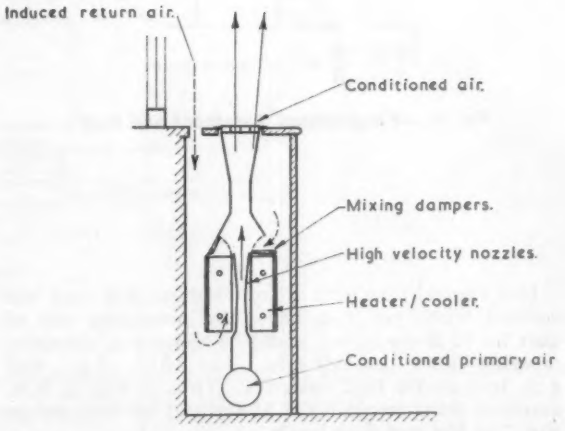


**Fig. 5.—Section through induction unit using mixing damper control**

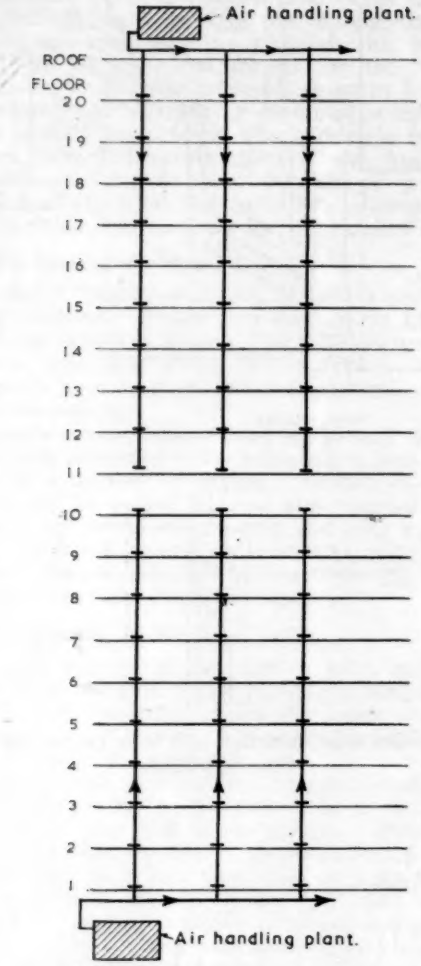


**Fig. 6.—Plant rooms, basement and roof**

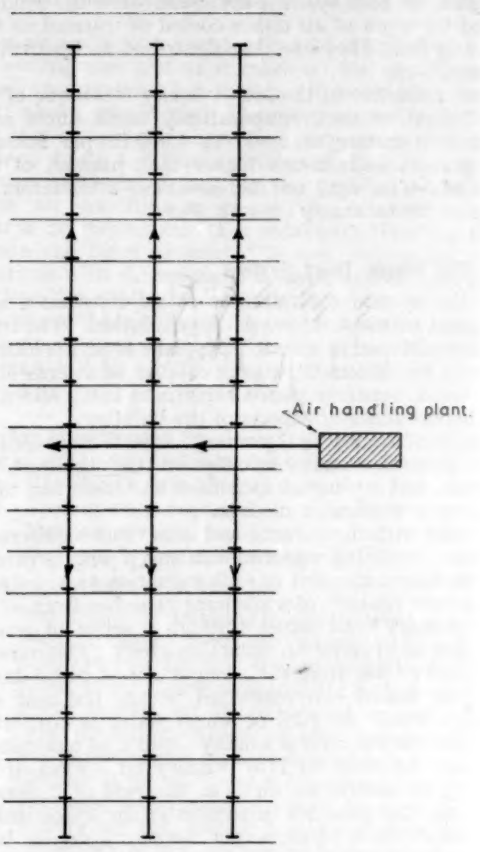


**Fig. 7.—Plant room at intermediate floor**

In a typical case with a bay width of 10 ft. and one vertical trunk per two bays, the maximum size of duct for 10 floors served would be about 9 in. diameter tapering down through 8 in., 7 in., 6 in., 5 in., and 4 in. to 3 in. for final run-outs. Thus in Fig. 6, 9 in. diameter ducts would occur at top and bottom, and in Fig. 7 at the mid-floor levels.

Another arrangement is as in Fig. 8 where main vertical trunks occur at the ends of the block, such as at the four corners. Horizontal run-outs are accommodated under the units below the windows, the columns probably being inset to allow the ducts and pipes to pass behind. The size of verticals may be perhaps 20 in. diameter reducing on the run. The horizontals might be 8 in. or 9 in. diameter tapering as before to 3 in. at the last unit served.

Fig. 9 shows part of a complete system in diagrammatic form.

With regard to operating conditions in a typical case :—

*Summer* outside temperature 80°F. D.B.
68°F. W.B.
Room condition 70°F. 50% R.H.
Primary air supply would be according to design at about 60°*F.* and about 55% R.H.
Water temperature to cooling coil = about 54° mean

*Winter* outside air 30°F.
Room condition 65°F. 50% R.H.
Primary air supply about 50°F.
Water temperature to coil for warming = up to about 120°F.

It is a feature of this system that at night time in winter, without fans running, sufficient heat is emitted from the coils by natural convection to maintain temperature in the rooms.

## 13. The Double Duct or All-Air System

The conditioning plant for the double duct system as in Fig. 10 is arranged to deliver air through two sets of ducts at two different temperatures, one cool at about 50°F. min. and one warm at about 120°F. max. varied according to outside temperature. The twin ducts follow similar routes to those of the single duct system, and terminate with connexions from each duct to the under-window units.

These units (see Fig. 11) are in effect blenders containing valves which admit varying proportions of cool and warm air according to the requirements of the controlling thermostat in the room. The unit also frequently contains a constant volume device to overcome the variations of pressure consequent on volume control. Induction takes place usually in the ratio of about 1 : 1.

The whole of the cooling load has to be carried by air not water and larger ducts are involved than with the single duct system but circulating pipes are eliminated. On the other hand a greater primary air ventilation rate is provided which is sometimes necessary in any event due to occupancy. Owing to the greater volume of primary air involved, a recirculation system is desirable so as to economise in cooling and heating.

Compared with the example given in Section 12 above, for the typical bay of 10 ft. wide × 20 ft. deep × 10 ft. high, the double duct system would be designed somewhat as follows :—

Cool air supply approximately—160 cu. ft/min.
(i.e. about 2½ times single duct)

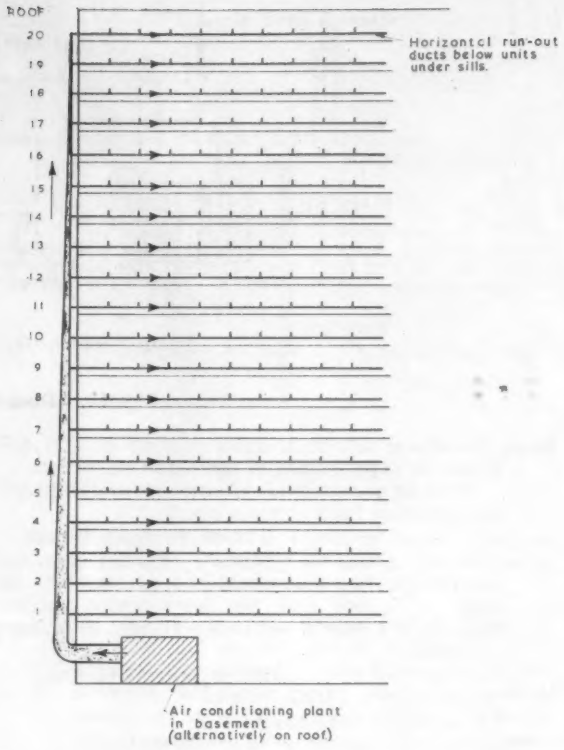


**Fig. 8.—Showing arrangement of ducts from main trunk at end of building**

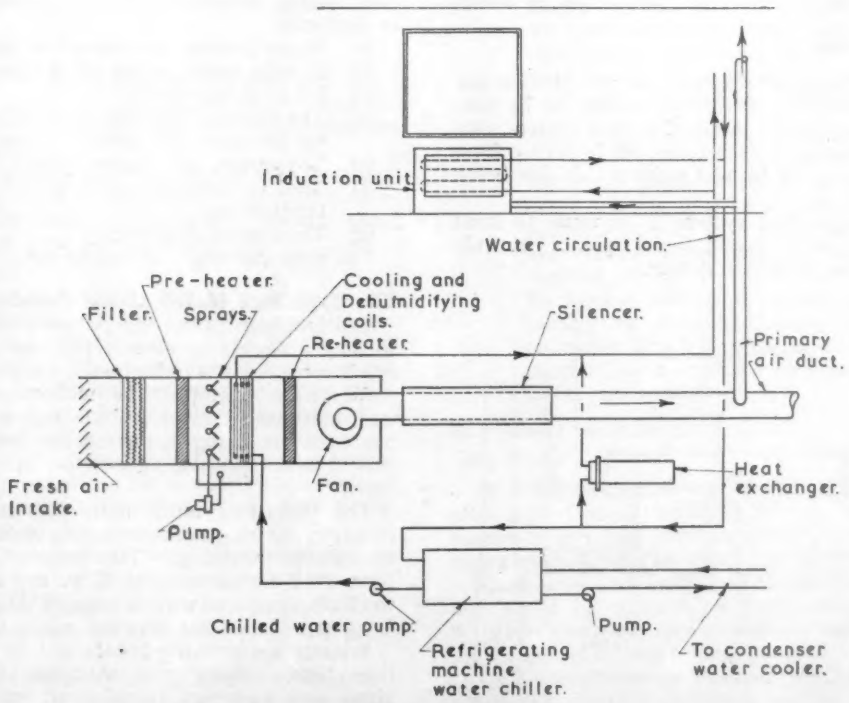


**Fig. 9.—Diagram of single duct induction system**

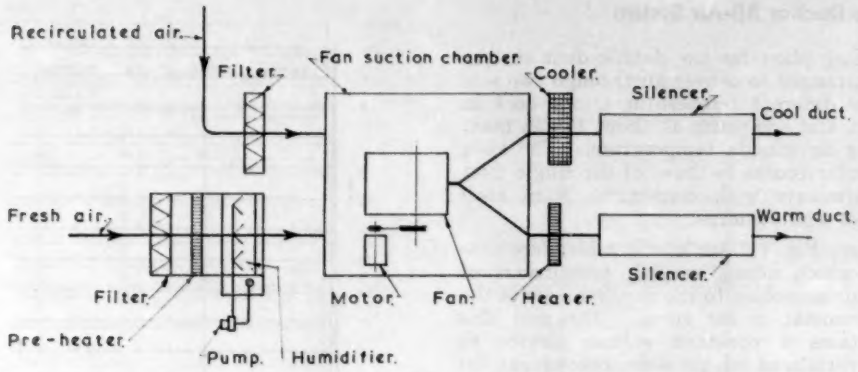


**Fig. 10.—Double duct plant diagram**

Warm air supply, 75% of cool—120 cu. ft/min.
(these air quantities are alternatives, not additive)
Recirculation back to main plant :
(summer)—90 cu. ft/min.
(winter)—50 cu. ft/min.
The refrigerating load would be approximately the same as before and the horse-power similar.
Duct sizes, 1 pair of verticals serving 2-10 ft. bays for 10 floors
Cool duct — 13 in. diameter tapering to 4 in.
Warm duct — 10 in. to 4 in.
Ducts require insulating.
There would however be no piping system.

The double-duct system having cool and warm air always available can serve any mixture of rooms such as, for instance, if some require cooling and others warming. It has furthermore no problem of change-over from summer to winter as no change-over occurs. The many pros and cons of the two systems require careful evaluation before a final choice can be made.

## 14. Interior Zones

Where office floors are planned in depth, the interior zones remote from the perimeter require to be considered. In the case of the double duct system, this presents no difficulty as such zones can be served from the same trunking, the blender units in this case being above false ceilings.

With the single duct system, it is usual to treat interior zones with conventional plants entirely separate from the perimeter system.

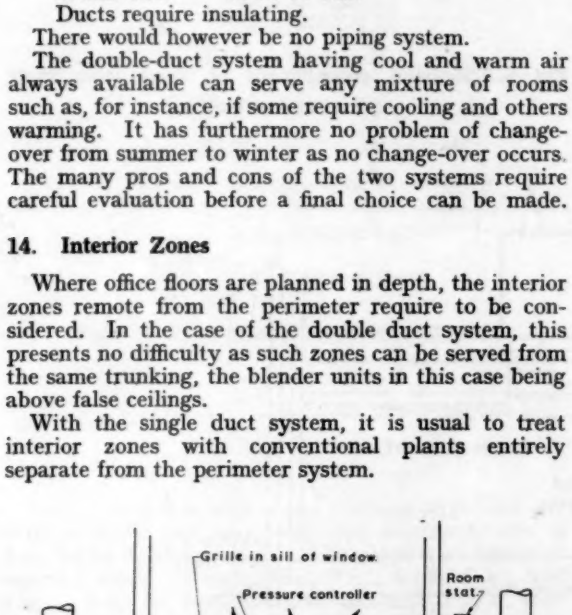


**Fig. 11.—Double duct unit with direct acting valves**

## 15. Cooling by Cooled Surfaces

An alternative method of cooling is by means of cooled surfaces, such as in the ceiling. This can only be done provided the space is air conditioned in some manner so as to ensure that the dew-point of air in contact with such surfaces is lower than the temperature of the surfaces themselves, otherwise condensation would occur. The same surfaces which are chilled in summer can be used for warming in winter.

The amount of air handled by the conditioning system can by this method often be reduced as the air quantity bears no relationship to the amount of sensible cooling necessary and hence some economy in overall plant capacity can be effected.

One notable example of a tall building in London is being equipped in this manner.

**16. To summarise** at this point, the advent of tall buildings forces attention in the direction of air conditioning in spite of its cost owing to its ability to deal with

(a) Rapid heating up of rooms in sun
(b) Equally rapid cooling off of those in shade
(c) Effect of high winds
(d) The internal heat from growing use of electricity for machines and greater lighting intensities
(e) The elimination of atmospheric dirt
(f) The requirement for individual control of temperature
(g) The control of humidity.

The consequences structurally are referred to later.

## 17. Experience in U.S.A. and Canada

Tall buildings in the U.S.A. and Canada have been so long accepted as normal practice that treatment has become fairly standardised.

All recent examples are without exception fully air conditioned and older buildings where such does not exist are being converted for the simple reason that it is not possible to let office space without this service.

The climate is much more extreme than in this country rendering summer cooling virtually a necessity for efficient working. The design temperature for New York for instance is 97°F. dry bulb and 76°F. wet bulb, compared with London 82° D.B. and 66° W.B. Long periods of hot weather come with regularity.

Winters are similarly colder and of longer duration than here. Opening of windows is impracticable. Many new buildings are planned with no provision whatever for opening of windows, cleaning being by external cradle.

The kind of systems described in paragraphs 12 and 13 above were developed in the U.S.A. specifically to meet the requirements of tall buildings and are extensively used.

Planning of office blocks is often in greater depth than here, having a core of elevators, toilets and ancillaries. Thus, as referred to earlier, it is common practice to provide separate inner zone conditioning systems, in addition to the perimeter system.

Much greater use is made of packaged units for air handling, refrigeration and boiler plant and, similarly, ductwork is often arranged for by an assembly of unit lengths and fittings rather than by the tailor-made methods found here. High cost of labour is partly responsible for these methods.

**18. Scandinavia**

The main problem in the Scandinavian countries, for example Sweden, is heating in winter due to sub-zero temperatures. Greatest possible attention is paid to insulation of buildings, the fitting of double windows, the design and air-tightness of windows and of doors.

Need for economy of heat has brought about the development of heat exchange apparatus for using warm exhaust air to heat cold incoming air.

The necessities are heating—because of the low temperatures—and ventilation—because owing to the tight fit of all windows and doors, occupants would suffocate otherwise. Summer cooling is less important, though in the tall blocks to be found in Stockholm refrigerating plant is often included to give a modest reduction of temperature.

The single duct induction system shown in Fig. 5 was developed in Sweden and is to be found in extensive use together with others of similar principle.

It is common practice to serve each aspect with a separate zone plant, leaving individual control to the occupant by hand adjustment.

Buildings are not usually planned in depth and hence in order to avoid external riser ducts, extensive use is made of sub-ceilings for run-outs from main risers in the centre.

**19. Europe**

In Germany, Holland, Belgium, France and Italy, tall buildings are facing the same problems and the methods adopted for heating and air conditioning are similar in principle.

A form of induction unit manufactured in Germany is shown in Fig. 12 and is interesting in that it combines cooling or warming by water backed panel surfaces, with air conditioning in one unit.

**20. Stack Effect**

That there must be a strong stack effect in tall buildings is obvious, due to temperature difference inside to outside. This channels through the staircases and lift shafts. If each floor is isolated by doors, as would be necessary to meet escape regulations, there is no reason why stack effect should concern individual offices.

Ground floor entrance halls and the like clearly require boosting with warm air in winter to counteract incoming cold draughts. Circular rotating doors would appear to be a necessity.

Landings on intermediate floors are best heated by radiant forms of heating rather than convection.

**21. Tall Block of Flats**

The above discussion has been concerned with office blocks.

The case with blocks of flats is different since in this country domestic air conditioning is not seriously contemplated.

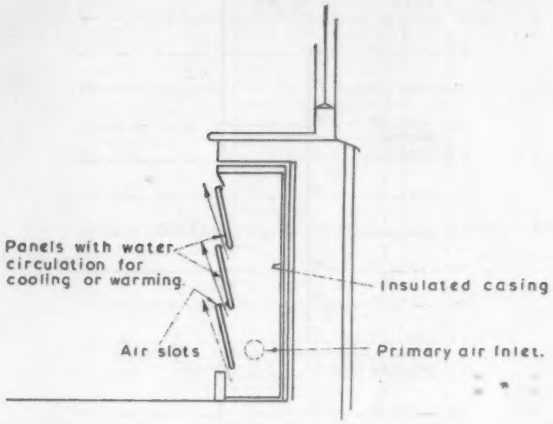


**Fig. 12.—A German single duct unit combining panel cooling and warming**

The heating of flats is therefore dealt with on conventional lines, generally by one of the following methods :—

(a) By central heating system with boiler in basement or on roof or at a remote point serving several blocks ; the same boiler plant to supply hot water supply through calorifiers locally or on a central distribution. Due to high pressures on lower floors ordinary radiators cannot be used unless the system is split, but convectors may be suitable.
Schemes have been developed using quiet fan convectors heated by hot water, one per flat, with ducted warm air to the rooms.

(b) Gas fired warm air units, delivering warm air to each room. These can be connected to a common air and vent duct known as an Se duct so eliminating individual flues. Hot water is sometimes combined with the heater or provided by means of separate instantaneous heaters.

(c) Electric floor warming. In view of the remarks under 9 it is open to question whether this is likely to prove entirely satisfactory where great differences of solar gain occur as between different aspects with the possibility of severe overheating on the sunny side with no means of shutting off.
Mechanical ventilation in tall blocks of flats is usually confined to the internal toilets and bathrooms for which a common shaft is frequently provided with duplicate electrically driven fans at the top on the roof.

**22. Water Services**

*Cold Water*

In order to reduce load on the structure there is often a good case for including main water storage in the basement and pumping therefrom to smaller tanks at upper levels serving the down feeds to the various floors.

These small tanks may be of say two hours capacity and would be situated on roof and at intermediate floor levels as necessary in order to limit the pressure on the lowest fittings served to about 120 ft. to 150 ft.

This arrangement is shown in Fig. 13. It will be noted that cascade pumping on the rising main is shown which reduces head on any one pump.

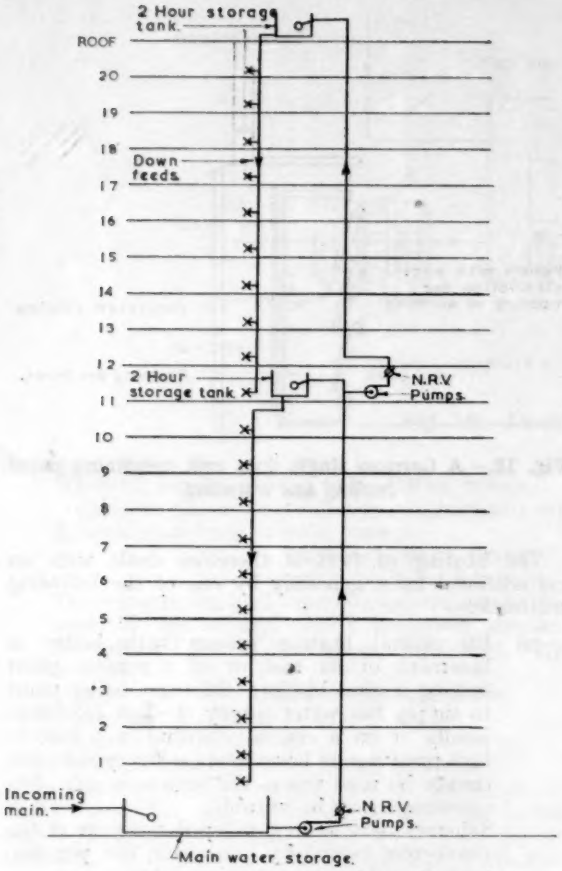


**Fig. 13.—Diagram of cold water system**

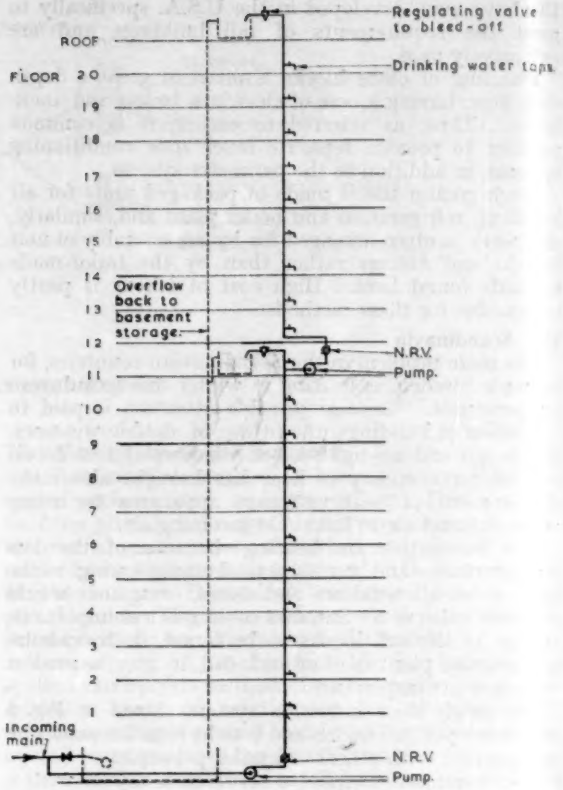


**Fig. 14.—Diagram of drinking water system**

Drinking water is a separate problem and must come off the rising main. In Fig. 13 the rising mains draw on the basement tank, however, and it would therefore be preferable to take small independent feeds with continuously running pumps for drinking water only as in Fig. 14. A bleed off the top of each riser into the down service tanks (in turn overflowing back to basement storage) will ensure some circulation of water taking place in the drinking water system even if all taps are shut off.

Another arrangement, where mains pressure permits, is as shown in Fig. 15. In this system mains pressure serves tanks at an intermediate level to deal with the lower floors and to serve the drinking water taps, the upper levels being dealt with by means of booster pumps.

Another alternative solution to this problem of water supplies to tall buildings is the provision of a pressure cylinder booster station in the basement, serving a common rising main and using reducing valves to break down the pressure of various levels to serve tanks for down feeds and drinking water taps.

*Fire Services*

Requirements will no doubt vary according to different Fire Authorities and type and planning of building.

In one London building the arrangement is as in Fig. 16. It will be noted that there are duplicate water supplies feeding a break tank in the basement. From these, duplicate booster fire pumps deliver to fire risers serving landing valves and hose reels. Hose reels on the lower floors are served direct from the main.

One of the pumps is electrically driven and starts automatically whenever a hose reel or landing valve is operated. The second pump is diesel driven and starts automatically if the electric pump does not maintain pressure.

As is often the case, the building contains a basement garage which is served by a conventional sprinkler system entirely independently.

*Hot Water Supply*

The same problem of dividing the building into tiers so as to limit head pressures arises in the case of hot water as with cold.

One method of dealing with this is as shown in Fig. 17. Calorifiers occur in the basement fed from tankage at an intermediate floor, serving the lower floors.

A second set of calorifiers is provided at the intermediate floor to serve the upper floors from tankage on the roof.

If more storeys are involved, the arrangement repeats.

The calorifier primary coils are fed by hot water or steam from the boiler plant in a normal manner.

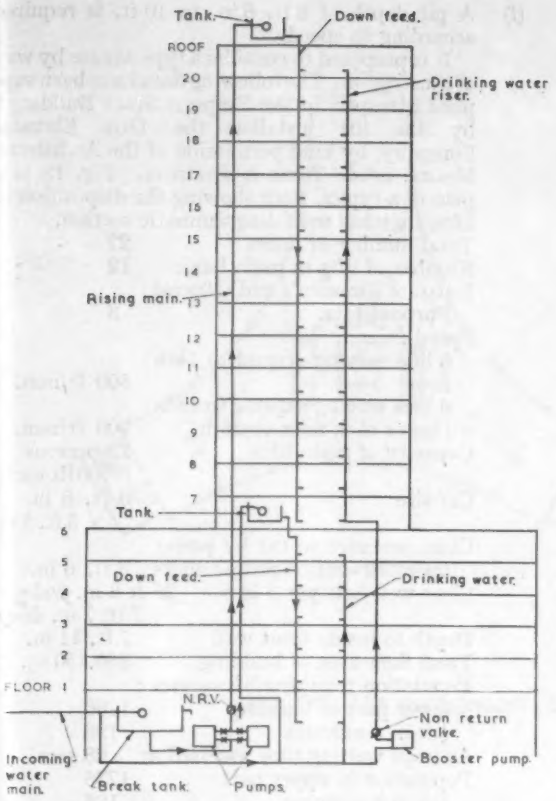


**Fig. 15.—Diagram of cold water supply system, where mains pressure serves lower floors**

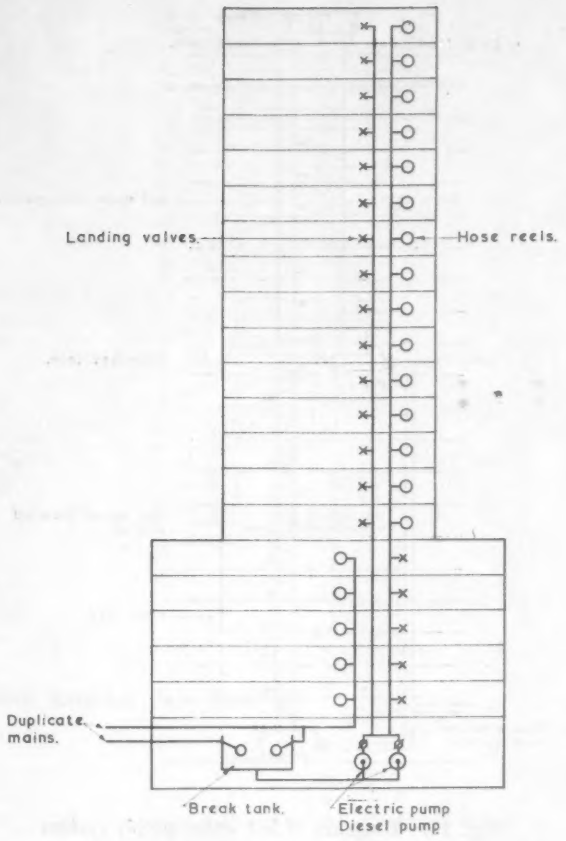


**Fig. 16.—Fire services for a particular case**

### 23. Sanitation

The conventional *two pipe system* can be eliminated for tall buildings on account of its complications when applied to multiple storeys.

The *one pipe system* reduces the amount of piping by combining soil and waste, also anti-syphon and vent pipes.

It appears however that the more recent *single stack system* has much to recommend it for tall buildings as soil, waste, anti-syphon and vent pipes are all catered for in one pipe. It has been in use on the Continent for a considerable time. It should be the most economical, and with careful design should prove itself here. As with any system, air compression must be allowed for and deep-seal traps throughout are a necessity.

Velocity breaks in verticals are usually provided at about every seventh floor. These may take various forms, such as an off-set of adequate length. Lower floors are frequently connected separately.

Rainwater similarly needs a 'velocity break' in any vertical or alternatively a surge tank at the bottom.

### 24. Electrical Services

A problem arises in the design of the lighting installation for a tall building as a result of the glare of strong light near windows. Areas remote from windows tend to be low in lighting intensity by contrast and hence the need for additional illumination up to about 50 lumens per sq. ft.

For 20 to 30 storeys distribution does not appear to present any unusual problems, copper busbars are normal but of greater size to allow for voltage drop. For greater heights sub-stations at intermediate plant floor levels will no doubt become necessary, using air cooled transformers and air break switchgear so as to avoid the fire hazard of oil. The latter are, however, not readily available in this country as yet.

### 25. Lifts

The vital importance of an adequate lift service in a tall building need not be stressed; it is impossible to walk upstairs 20 or 30 floors.

There are many factors bearing on this problem in arriving at the best size, number and speed of lifts required, not perhaps apposite to discussion here. Certain main principles are, however, clear and may be stated as follows :—

(a) One central group of lifts gives far better service and shorter waiting time than two or more groups with the same number of lifts in total.

(b) Cars which are wide rather than deep allow quicker transfer time. Transfer time, i.e. getting in and out at landings, occupies more time in a round trip than the travel itself.

(c) The different groups of floor levels may be considered as separate buildings, one above the other and served by lifts as follows :—

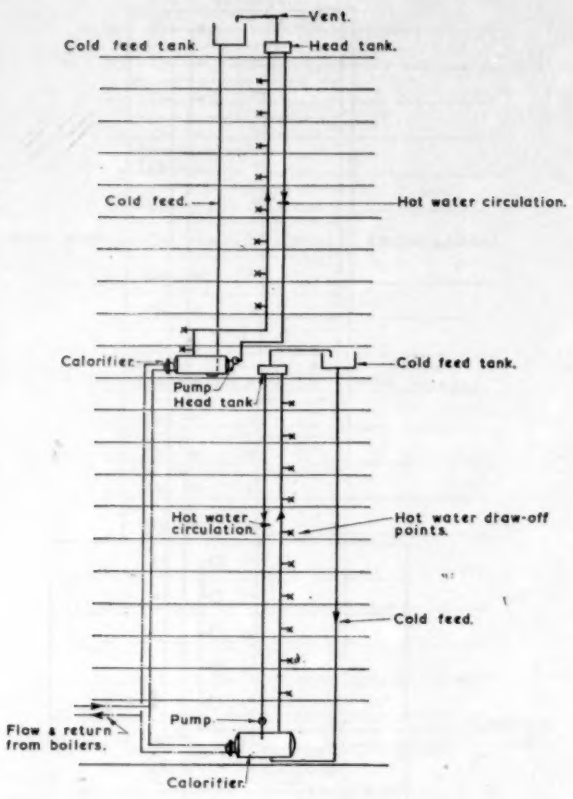


**Fig. 17.—Diagram of hot water supply system**

One bank of lifts to serve all floors up to about 15th at a speed of — 500 ft. per min.
One bank express from ground to 16th then stopping at all floors to 30th — 700 ft. per min.
One bank express from ground to 31st then stopping at floors above — 1000 ft. per min.

(d) The type of occupancy affects lift provisions. Thus, if occupied by a single firm it is estimated that at least $\frac{1}{8}$th of the population should be moved in five minutes. Even so, if all arrive at once, it would take 30 minutes to populate the building, and some of the staff would arrive half an hour late.
Some staggering is thus inevitable.
Alternatively, if occupancy is of mixed tenancy some staggering is inherent and a service to handle $\frac{1}{8}$th of the population in five minutes appears to be a safe assumption.

(e) The lift motor room must be at the top of the well-hole, i.e. at roof for full run lift bank, and at intermediate floor(s) for the shorter run banks. Bottom gears are impracticable.
Over-run and machine room space require considerable height. The following examples illustrate height from top floor served to underside of lifting joist over machine.

| | |
|---|---|
| 500 ft/min. | 27 ft. 10 in. |
| 700 ft/min. | 32 ft. 3 in. |

(these vary somewhat according to load and hence size of machine).

(f) A pit depth of 8 ft. 6 in. to 10 ft. is required according to speed.
It is proposed to consider a typical case by way of illustration. The following data have been supplied in respect of the Empress State Building* by the lift installers the Otis Elevator Company, by kind permission of the Architects, Messrs. Stone Toms & Partners. Fig. 18 is a plan of a typical floor showing the disposition of lifts, together with diagrammatic section.

| | |
|---|---|
| Total number of floors | 27 |
| Number of lifts in main bank | 12 |
| Separate Firemen's and General Purpose lifts. | 3 |
| Speed : | |
| 6 lifts serving ground to 14th floor | 500 ft/min. |
| 6 lifts serving express to 15th thence each floor to 26th | 700 ft/min. |
| Capacity of main lifts | 23 persons (3500 lb. each) |
| Car size | 6 ft. 8 in. × × 5 ft. 5 in. |
| Clear entrance to car by power operated centre opening doors | 3 ft. 6 in. |
| Clear well-hole per 3 lifts | 25 ft 8 in. wide × 7 ft. 7 in. deep. |
| Depth to inside front wall | 7 ft. 11 in. |
| Total floor area of building | 350,450 sq. ft. |
| Population requiring lift service : | |
| lower part of building | 1766 |
| $\frac{1}{8}$th in 5 minutes | 196 |
| Average waiting time assessed at | 28 secs. |
| Population in upper part | 1775 |
| $\frac{1}{8}$th in 5 minutes. | 198 |
| Average waiting time | 30 secs. |
| System of control | Automatic programme. |

Perhaps the most important aspect of design to stress is that in the early stages of structural layout first consideration should be given to the provision of adequate clear well-hole dimensions for the lifts. It becomes, in effect, designing the lifts first and fitting the building around them afterwards. Reference has already been made to width being preferable to depth, which in turn may affect the constructional module.

## 26. Structural Requirements

The Structural Engineer is probably involved to a much greater extent in meeting requirements for services for tall buildings, than in those of more normal height. In other words the engineering of the building in all its respects is more closely integrated due to the special problems involved in building high.
Some of these provisions have been mentioned in the Paper, but may be summarised thus :—

(a) *Air Conditioning*

(i) Provision for plant loadings at basement, roof and possibly at intermediate floors

(ii) Provision for cooling tower on roof or elsewhere

(iii) Holes for air supply ducts
a. on perimeter of building—this might affect beam arrangement
b. or at extremities of building—this might involve shafts as part of end walls
c. or internally—this assumes false ceilings to accommodate run outs

* A City Centre Properties Development.

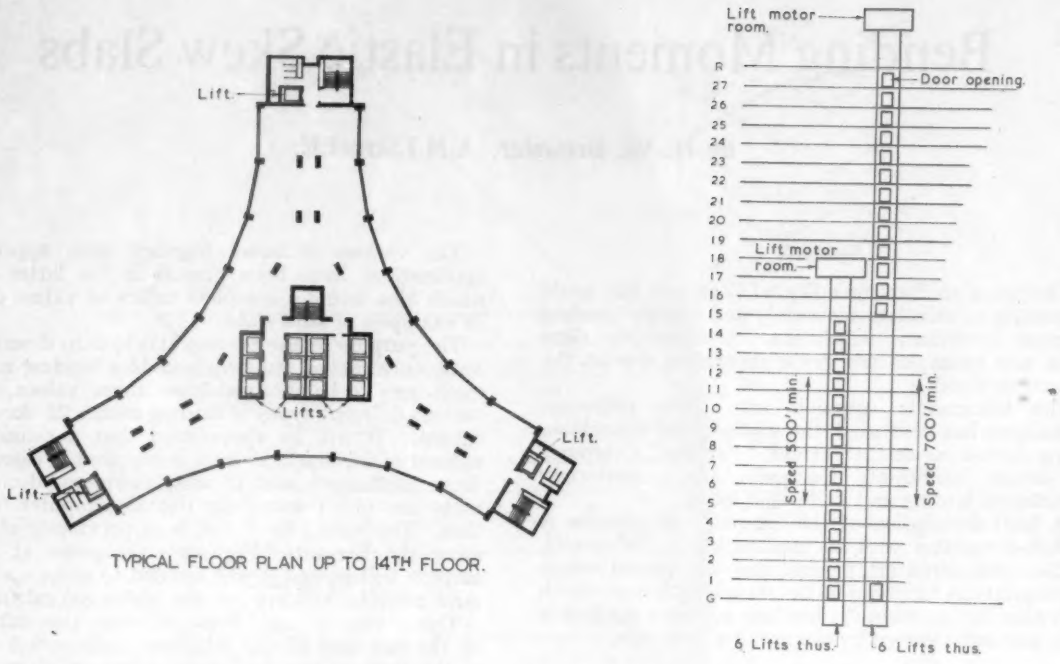


**Fig. 18.—Lift arrangement—28-storey Empress State Building**

(iv) Holes for extract ducts.
These would generally occur in the inner core possibly combined with shafts for sanitary and other services.

(v) Insulation of roof and walls. Tile or other sun reflective surface on roof.

(vi) Sun breaks in hot climates designed to give maximum shade on the different aspects.

(vii) Windows to be well designed structurally, preferably double glazed. If openable for cleaning, to have good weather seal and adequate clamping action fastenings.

(b) *Heating*

(i) Normal structural provisions for boiler house and flue.
Consideration may be given to boiler house on roof to avoid lengthy flue.

(ii) Normal provision for holes for pipes.

(c) *Water Services*

(i) Consideration of main storage in basement—possible use of concrete tanks.

(ii) Provision for load of tankage at roof and at intermediate floor(s).

(iii) Provision for carrying pumps at intermediate floor(s) if required and at basement.

(vi) Provision for carrying hot water supply calorifiers at intermediate floor(s).

(v) Normal provision for holes for piping.

(d) *Sanitation*

(i) Provision in design of pipe shafts for velocity breaks at about 7 floor intervals.

(ii) Provision of normal holes for pipes throughout.

(e) *Electrical*

(i) For buildings of unusual height or having special requirements, provision for carrying the load of transformers and switchgear at an intermediate floor may be involved.

(ii) Provision for electrical vertical risers is required generally in the form of a slot with a small room on each floor for distribution boards, telephone boards, etc.

(f) *Lifts*

(i) Provision for load of lift gear at roof and at intermediate floor level(s).

(ii) Shafts of adequate dimensions to allow wide entrances rather than narrow. Shafts to be constructed plumb or with a tolerance for inaccuracy in construction.

(iii) Fronts must be accurately linable floor to floor.

(iv) Provision for lift pits and over-runs to dimensions dictated by speed.

(v) Provision of traps for plant removal, also lifting joists over machines.

It will be noted that frequent reference is made to the use of an intermediate floor for plant. This provision can simplify plant arrangement considerably and, although apparently wasting space, may actually be an economy. Such a floor can house :—

Air Conditioning plant and Main ducts.
Exhaust fans.
Cold Water tanks.
Hot Water calorifiers.
Pumps.
Lift Gear.

Access to all such plant is facilitated and this should make for improved service and maintenance throughout the life of the building.

**References**

1. *I.H.V.E. Guide to Current Practice* 1959.
2. *A.S.H.A.E. Guide* 1961.
3. " The Heating of Buildings by Off-Peak Electricity Supplies " The H. & V. Research Association. May 1961, p. 27.

# Bending Moments in Elastic Skew Slabs

by D. W. Brewster, A.M.I.Struct.E.

**Synopsis**

The use of an Electronic Digital Computer has made it possible to calculate accurately and quickly bending moment coefficients which arise in monolithic skew slabs and examples are given showing a few of the figures obtained.

The biharmonic equation with finite difference techniques has been used, the whole of the calculation being carried out on the Ferranti 'Pegasus' Computer to obtain coefficients for point loads, uniformly distributed loading and knife edge loads.

A brief description of the computer programme is included together with an explanation of the results.

The coefficients are general and are quoted where appropriate as functions of the skew length from which it is possible to obtain the bending moments applicable to a particular design by the use of a slide rule.

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The calculation of bending moment coefficients for elastic skew slabs depends upon the biharmonic equation :

$$N \nabla^4 w = q$$

where :

$w$ is the deflexion

$q$ is the intensity of loading

$N$ is the stiffness of the slab $= \dfrac{Eh^3}{12(1-\mu^2)}$

The solution of this equation for any one example will also require consideration of the end and edge conditions.

$Mx$ then equals $-N\left(\dfrac{\partial^2 w}{\partial x^2} + \dfrac{\mu \partial^2 w}{\partial y^2}\right)$

$My$ $\quad -N\left(\dfrac{\partial^2 w}{\partial y^2} + \dfrac{\mu \partial^2 w}{\partial x^2}\right)$

$Mxy$ $\quad -N\left(1-\mu\right)\dfrac{\partial^2 w}{\partial x \partial y}$

$\mu$ = Poissons ratio taken as ·15

In calculating bending moments from deflexions the value of $N$ cancels and has, therefore, been ignored by being put equal to unity in the work which has been carried out.

The notation adopted is the same as that used by Dr. Robinson in Research Report No. 8 published by the Cement and Concrete Association.

To enable a useful solution to be obtained it is possible to make use of finite difference equations by covering the skew deck with a network. Values of $w$ at all nodes can be evaluated and from these values bending moments $Mx$, $My$ and torsion moment $Mxy$ can be obtained.

The basic finite difference equations have been set out by Jensen in the *University of Illinois, Engineering Experiment Station Bulletin*, September 1941, pp 112, Series No. 332 and have been used by Dr. Robinson in the publication by *C. & C. A. Research Report* No. 8.

The various formulae together with appropriate explanations have been quoted in the latter article which also includes complete tables of values of $k$ for 25 examples of skew slabs.

The purpose of the present article is to describe the work since carried out which enables bending moment coefficients to be obtained from these values of $k$ for various different types of loading on the 25 skew slabs chosen. It will be appreciated that a considerable amount of arithmetical work is involved in calculating these coefficients and it was, therefore, decided to make use of an automatic digital computer for this task. The values for $k$ had been previously obtained using the Ferranti 'Pegasus' Computer at Northampton College and it was decided to make use of the same machine to carry out the additional calculations.

This choice to use 'Pegasus' was also influenced by the fact that all the deflexion coefficients $k$ existed in the form of punched paper tapes which were the results of the previous calculation. This has meant that the figures can be fed back into the machine without re-writing, thus saving considerable time and what is more important remove the possibility of error in transcription.

It was, therefore, necessary to prepare a computer programme that would allow the existing result tapes to be used as data tapes for the work to be carried out and to produce the different bending moment coefficients required.

As it was necessary to obtain the coefficients for use in various bridge designs it was decided to obtain B.M. coefficients for uniform loading on the complete deck, a knife edge load along the middle grid line and to be able to find coefficients for a point load applied to any position. This would enable practical designs to be made for loading in accordance with B.S.153 for H.A. and H.B. and R.A. and R.B. loadings.

To enable uniform loading coefficients to be worked out it will be realized that coefficients for $Mx$, $My$ and $Mxy$ for a load at every node point would be required and in the examples considered 45 nodes occurred apart from the ends where $w$ would be zero. This results in $45 \times 3 \times 23$ coefficients arising, i.e., a total of 3,105 and each involving a large number of separate arithmetical operations. As the different loading arrangements required the various coefficients added together in different ways and as it is also possible that further different combinations might be required it was decided to calculate systematically all coefficients for a particular example and these are stored permanently in the form of paper tape for possible further use at a later stage.

The first portion of the programme, which has been written in 'Pegasus' autocode, consists of instructions for 'reading in' the deflexion coefficients in the sequence required together with certain other data and calculating the 3,105 coefficients in the form of five separate tapes, one for each of the five lines across the deck as shown in Fig. 1. The computer takes approximately 35 minutes machine time to calculate the 621 coefficients required for each line. The 621

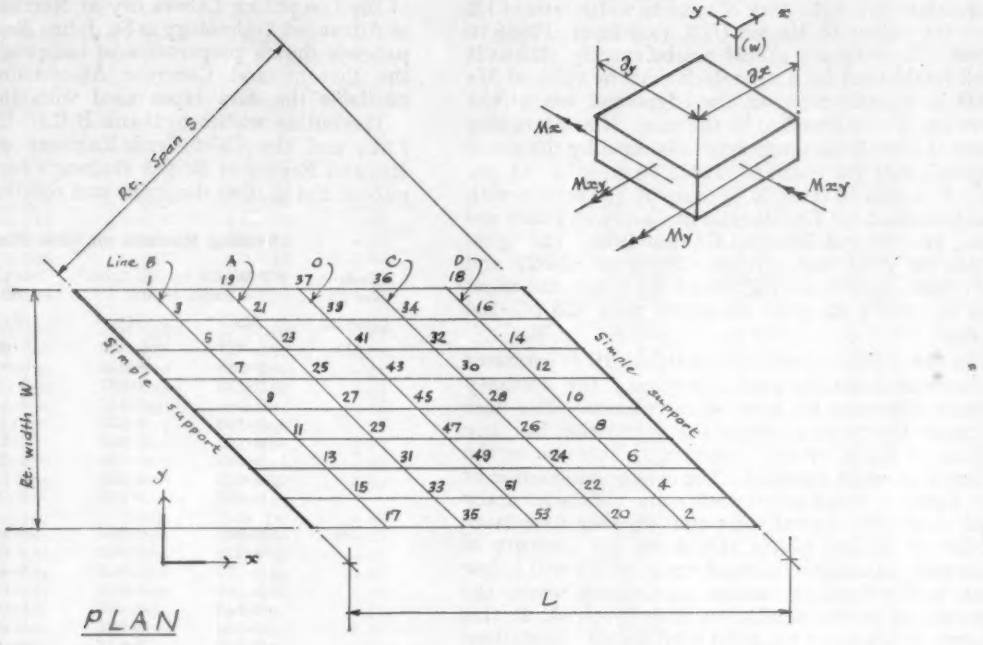


Fig. 1.

coefficients consist of three figures for each of the nine points for the 23 load positions on one end of the bridge, the coefficients for loads on the other end being obtained by symmetry.

The next part of the programme selects and prints the coefficients for point loads taken separately along the centre line across the deck as shown in Tables 2a, b, c, d, & e. It is of interest to note that together with the coefficients the printing instructions also record the point at which the load acts and the point at which the B.M. coefficients occur. This is an important part of the work and a technique carried through the complete programme including a record on the intermediate data tapes to ensure that the coefficients are always related to the correct loading points and coefficient points. The example number which determines the proportions and angle of the slab is also recorded and printed to avoid errors arising in interpretation of results.

It has also been possible to insert certain instructions in the programme that ensure the correctness of the group of data provided for a given problem. The calculation will not commence unless the different data items are applicable to one another and unless further numbers necessary have been specified. This will prevent deflexion coefficients for one example being used with ratios and angles of a different example and will stop the calculation if the indices are not given controlling the printing of load points and bending moment points and other decisions taken by the machine during the calculation. This point requires serious consideration in programme writing as the capacity of the computer to generate numbers is enormous and it is a real problem to avoid being presented with a large number of almost meaningless figures not related properly to the problem.

To provide coefficients for total uniform load every similar coefficient must be added together making allowance for half unit loads acting on the edge and centre nodes and these to be reversed to allow for loading on the unsymmetrical half and the two sets of figures added together. It has also been arranged for the coefficients to be presented as a factor of $qL^2$ where $L$ is the skew length of the bridge. This enables a direct relation to be made to $\cdot 125\ qL^2$ and it will be seen in Table 3 that the result of designing as a monolithic plate has reduced the coefficients from $\cdot 125$ to $\cdot 055\ qL^2$.

To obtain coefficients for a knife edge load along the centre grid line it is necessary to use the coefficients for loads on points 37, 39, 41, 43, 45, 47, 49, 51 and 53 added in the appropriate manner and these are shown in Table 4. These coefficients are a factor of $WL$ and as in the case of $UDL$ a considerable reduction can be seen compared with $\cdot 25\ WL$. The maximum figure is at point 35 where the coefficient is $\cdot 141\ WL$. In these tables the notation :

| | | |
|---|---|---|
| *UDL* | indicates | uniformly distributed load |
| *KEL* | ,, | knife edge load along centre line of mesh |
| $\cdot 5UDL$ | ,, | uniformly distributed loading on one side of the deck. |

Although a large reduction in $Mx$ is obtained compared with designing as freely supported separate units considerable reinforcement or prestressing is required to deal with bending moment $My$ and twisting moments $Mxy$. It is possible that the saving in cost may be small but considerable saving will be made in construction depth which apart from saving weight and materials may be of importance in giving greater headroom.

It was also considered necessary to investigate the effect of loading one lane of the bridge only to see if the transverse moments would be greater. In this example see Table 5 the values $My$ and $Mxy$ under this form of loading are less than for total uniform load but this is not necessarily the case for all ratios of span to width and skew.

It is of interest to consider the coefficients in Table 6 which relate to a right deck of span to width ratio of 1/2 where the values of *Mx* for *UDL* vary from ·12955 to ·12388. These figures should not be exactly ·125 as it is well established for a right deck that the value of *Mx* should be slightly more at the edges and less at the centre and this is found to be the case. It is interesting to note that with the mean figure obtained by the use of Simpson's rule the result is ·12482 an error of ·14 per cent. It is also of interest to compare the results with those published by Timoshenko in *Theory of Plates and Shells*, pp. 218 and 219, 2nd Edition 1959. The figure for *Mx* for *KEL* varies from ·25844 to ·24827 and again these figures are highest at the edge ; the mean value is ·24974 an error compared with ·25 of ·104 per cent.

This comparison of accuracy justifies further comment as reasonable doubts exist concerning the accuracy of finite difference methods of calculation. The finer the mesh the more accurate the calculation but any increase in accuracy will result in an increase in the arithmetical work involved. The correct summation of these figures is also a useful confirmation of the accuracy of an electronic digital computer working to a large number of decimal places and shows the necessity of using such a machine to avoid errors which will follow many arithmetical operations particularly where the difference of similar numbers is often involved. In this example a computer has been used for all calculations from the beginning of the problem. It has been noted that the results of finite difference methods of calculation of bending moments carried out by Morley lead to more rapidly converging results in relation to the number of points used compared with deflexions.

One further facility is available as it is also possible to obtain bending moment coefficients at any node due to a unit point load applied to any other node point. A typical example can be seen in Table 7 and it will also be seen that principal moments *Mp* and *Mq* and the angles at which they act relative to the *x* and *y* axes are also given.

It will be appreciated that a considerable number of coefficients would be required if they should all be printed and it is proposed that the data should exist as punched paper tape and with the use of a short length of programme to produce coefficients for separate point loads as required. It will be seen that as previously stated the printing instruction will arrange for the position of the point load to be recorded together with the position of the bending moments and also the example number, span to width ratio and angle. Various combinations of point loads could be taken if a load is to be applied at a point other than a node and intermediate bending moments can always be obtained by interpolation.

To compile a complete set of coefficients for one example together with *UDL* and *KEL* figures will take approximately four hours machine time. This gives some idea of the large amount of arithmetical work involved when it is realized that single arithmetical operations take place in fractions of a second but more important is the fact without the accuracy of a computer the task would from a practical point of view be almost impossible.

Copies of the programme and necessary data tapes are available at Northampton College and Southampton University where results can be obtained for slabs of the skew and span to width ratio quoted in Table 8 and it should be noted that the whole range of results for the slabs given in Table 8 are being computed at the time of writing at the University of Southampton.

Particular thanks are due to the Principal and Staff of the Computing Laboratory at Northampton College of Advanced Technology in St. Johns Road for help and patience during preparation of the programme and to the Cement and Concrete Association for making available the data tapes used with the programme.

The author wishes to thank B.R.C. Engineering Co. Ltd., and the Chief Civil Engineer of the London Midland Region of British Railways for permission to publish the various diagrams and results.

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +37 | +0·021 | +0·000 | +0·000 | +1 |
| | +0·085 | —0·018 | +0·010 | +3 |
| | +0·228 | —0·097 | +0·034 | +5 |
| | +0·240 | —0·147 | +0·135 | +7 |
| | +0·180 | —0·136 | +0·155 | +9 |
| | +0·112 | —0·095 | +0·121 | +11 |
| | +0·063 | —0·056 | +0·078 | +13 |
| | +0·035 | —0·028 | +0·043 | +15 |
| | +0·023 | +0·000 | +0·000 | +17 |
| +39 | +0·007 | +0·000 | +0·000 | +1 |
| | +0·028 | +0·001 | +0·008 | +3 |
| | +0·077 | —0·008 | +0·019 | +5 |
| | +0·155 | —0·036 | +0·043 | +7 |
| | +0·148 | —0·066 | +0·096 | +9 |
| | +0·104 | —0·061 | +0·097 | +11 |
| | +0·063 | —0·041 | +0·072 | +13 |
| | +0·037 | —0·022 | +0·046 | +15 |
| | +0·028 | +0·000 | +0·000 | +17 |
| +41 | +0·001 | +0·000 | +0·000 | +1 |
| | +0·006 | +0·005 | +0·005 | +3 |
| | +0·019 | +0·013 | +0·010 | +5 |
| | +0·042 | +0·022 | +0·020 | +7 |
| | +0·094 | +0·016 | +0·028 | +9 |
| | +0·090 | —0·010 | +0·060 | +11 |
| | +0·064 | —0·017 | +0·061 | +13 |
| | +0·041 | —0·011 | +0·052 | +15 |
| | +0·037 | +0·000 | +0·000 | +17 |

**Table 2a**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +37 | +0·148 | +0·000 | +0·000 | +19 |
| | +0·376 | —0·069 | +0·004 | +21 |
| | +0·278 | —0·102 | +0·196 | +23 |
| | +0·150 | —0·082 | +0·209 | +25 |
| | +0·067 | —0·045 | +0·153 | +27 |
| | +0·028 | —0·020 | +0·091 | +29 |
| | +0·013 | —0·006 | +0·048 | +31 |
| | +0·007 | +0·003 | +0·022 | +33 |
| | —0·002 | +0·000 | +0·000 | +35 |
| +39 | +0·060 | +0·000 | +0·000 | +19 |
| | +0·144 | +0·009 | +0·026 | +21 |
| | +0·245 | +0·030 | +0·054 | +23 |
| | +0·163 | —0·012 | +0·140 | +25 |
| | +0·081 | —0·012 | +0·130 | +27 |
| | +0·037 | —0·005 | +0·087 | +29 |
| | +0·019 | +0·001 | +0·051 | +31 |
| | +0·012 | +0·005 | +0·026 | +33 |
| | +0·002 | +0·000 | +0·000 | +35 |
| +41 | +0·021 | +0·000 | +0·000 | +19 |
| | +0·050 | +0·017 | +0·024 | +21 |
| | +0·089 | +0·049 | +0·043 | +23 |
| | +0·159 | +0·094 | +0·045 | +25 |
| | +0·103 | +0·047 | +0·092 | +27 |
| | +0·054 | +0·024 | +0·081 | +29 |
| | +0·029 | +0·014 | +0·057 | +31 |
| | +0·021 | +0·009 | +0·033 | +33 |
| | +0·010 | +0·000 | +0·000 | +35 |

**Table 2b**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +37 | +0·595 | +0·000 | +0·000 | +37 |
| | +0·273 | —0·048 | +0·317 | +39 |
| | +0·083 | —0·028 | +0·261 | +41 |
| | +0·004 | +0·007 | +0·169 | +43 |
| | —0·013 | +0·015 | +0·089 | +45 |
| | —0·010 | +0·013 | +0·042 | +47 |
| | —0·006 | +0·010 | +0·018 | +49 |
| | —0·007 | +0·005 | +0·009 | +51 |
| | —0·005 | +0·000 | +0·000 | +53 |
| +39 | +0·253 | +0·000 | +0·000 | +37 |
| | +0·349 | +0·175 | +0·102 | +39 |
| | +0·140 | +0·040 | +0·201 | +41 |
| | +0·033 | +0·035 | +0·152 | +43 |
| | —0·000 | +0·030 | +0·087 | +45 |
| | —0·005 | +0·021 | +0·045 | +47 |
| | —0·003 | +0·013 | +0·021 | +49 |
| | —0·005 | +0·007 | +0·011 | +51 |
| | —0·004 | +0·000 | +0·000 | +53 |
| +41 | +0·102 | +0·000 | +0·000 | +37 |
| | +0·166 | +0·054 | +0·085 | +39 |
| | +0·225 | +0·254 | +0·095 | +41 |
| | +0·084 | +0·104 | +0·125 | +43 |
| | +0·024 | +0·060 | +0·085 | +45 |
| | +0·007 | +0·035 | +0·051 | +47 |
| | +0·004 | +0·020 | +0·027 | +49 |
| | —0·000 | +0·009 | +0·015 | +51 |
| | —0·001 | +0·000 | +0·000 | +53 |

**Table 2c**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +37 | —0·153 | +0·000 | +0·000 | +18 |
| | —0·158 | +0·122 | +0·145 | +16 |
| | —0·083 | +0·074 | +0·025 | +14 |
| | —0·040 | +0·038 | +0·003 | +12 |
| | —0·020 | +0·019 | —0·001 | +10 |
| | —0·011 | +0·010 | —0·001 | +8 |
| | —0·006 | +0·004 | —0·000 | +6 |
| | —0·002 | +0·001 | +0·000 | +4 |
| | —0·001 | +0·000 | +0·000 | +2 |
| +39 | —0·085 | +0·000 | +0·000 | +18 |
| | —0·130 | +0·122 | +0·134 | +16 |
| | —0·074 | +0·078 | +0·024 | +14 |
| | —0·038 | +0·041 | +0·004 | +12 |
| | —0·019 | +0·022 | —0·000 | +10 |
| | —0·011 | +0·011 | —0·000 | +8 |
| | —0·006 | +0·005 | +0·000 | +6 |
| | —0·002 | +0·001 | +0·000 | +4 |
| | —0·001 | +0·000 | +0·000 | +2 |
| +41 | +0·067 | +0·000 | +0·000 | +18 |
| | —0·071 | +0·120 | +0·113 | +16 |
| | —0·057 | +0·084 | +0·023 | +14 |
| | —0·034 | +0·048 | +0·005 | +12 |
| | —0·019 | +0·026 | +0·001 | +10 |
| | —0·011 | +0·014 | +0·000 | +8 |
| | —0·006 | +0·006 | +0·000 | +6 |
| | —0·003 | +0·002 | +0·000 | +4 |
| | —0·001 | +0·000 | +0·000 | +2 |

**Table 2e**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +37 | +0·144 | +0·000 | +0·000 | +36 |
| | —0·030 | +0·011 | +0·274 | +34 |
| | —0·075 | +0·059 | +0·162 | +32 |
| | —0·054 | +0·048 | +0·067 | +30 |
| | —0·030 | +0·029 | +0·026 | +28 |
| | —0·016 | +0·017 | +0·009 | +26 |
| | —0·010 | +0·009 | +0·004 | +24 |
| | —0·006 | +0·003 | +0·003 | +22 |
| | —0·003 | +0·000 | +0·000 | +20 |
| +39 | +0·332 | +0·000 | +0·000 | +36 |
| | +0·044 | +0·035 | +0·233 | +34 |
| | —0·044 | +0·075 | +0·148 | +32 |
| | —0·042 | +0·058 | +0·066 | +30 |
| | —0·026 | +0·035 | +0·028 | +28 |
| | —0·014 | +0·020 | +0·011 | +26 |
| | —0·009 | +0·010 | +0·006 | +24 |
| | —0·006 | +0·004 | +0·003 | +22 |
| | —0·003 | +0·000 | +0·000 | +20 |
| +41 | +0·208 | +0·000 | +0·000 | +36 |
| | +0·153 | +0·091 | +0·102 | +34 |
| | +0·007 | +0·112 | +0·109 | +32 |
| | —0·021 | +0·079 | +0·060 | +30 |
| | —0·018 | +0·048 | +0·031 | +28 |
| | —0·011 | +0·027 | +0·015 | +26 |
| | —0·008 | +0·013 | +0·008 | +24 |
| | —0·005 | +0·005 | +0·005 | +22 |
| | —0·003 | +0·000 | +0·000 | +20 |

**Table 2d**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| *UDL* | +0·004 | +0·000 | +0·000 | +1 |
| | +0·008 | +0·001 | +0·004 | +3 |
| | +0·012 | +0·002 | +0·007 | +5 |
| | +0·013 | +0·003 | +0·009 | +7 |
| | +0·012 | +0·006 | +0·011 | +9 |
| | +0·009 | +0·010 | +0·012 | +11 |
| | +0·004 | +0·014 | +0·013 | +13 |
| | —0·001 | +0·018 | +0·026 | +15 |
| | +0·010 | +0·000 | +0·000 | +17 |
| | +0·014 | +0·000 | +0·000 | +19 |
| | +0·018 | +0·004 | +0·010 | +21 |
| | +0·019 | +0·007 | +0·014 | +23 |
| | +0·016 | +0·012 | +0·017 | +25 |
| | +0·012 | +0·017 | +0·018 | +27 |
| | +0·009 | +0·020 | +0·020 | +29 |
| | +0·008 | +0·019 | +0·025 | +31 |
| | +0·016 | +0·009 | +0·027 | +33 |
| | +0·026 | +0·000 | +0·000 | +35 |
| | +0·023 | +0·000 | +0·000 | +37 |
| | +0·023 | +0·006 | +0·017 | +39 |
| | +0·017 | +0·013 | +0·022 | +41 |
| | +0·012 | +0·020 | +0·023 | +43 |
| | +0·010 | +0·022 | +0·022 | +45 |
| | +0·012 | +0·020 | +0·023 | +47 |
| | +0·017 | +0·013 | +0·022 | +49 |
| | +0·023 | +0·006 | +0·017 | +51 |
| | +0·023 | +0·000 | +0·000 | +53 |

**Table 3**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| *KEL* | +0·002 | +0·000 | +0·000 | +1 |
| | +0·008 | +0·001 | +0·003 | +3 |
| | +0·023 | +0·000 | +0·007 | +5 |
| | +0·034 | +0·002 | +0·018 | +7 |
| | +0·033 | +0·009 | +0·028 | +9 |
| | +0·023 | +0·021 | +0·032 | +11 |
| | +0·007 | +0·037 | +0·037 | +13 |
| | —0·009 | +0·050 | +0·079 | +15 |
| | +0·025 | +0·000 | +0·000 | +17 |
| | +0·019 | +0·000 | +0·000 | +19 |
| | +0·047 | +0·004 | +0·012 | +21 |
| | +0·060 | +0·018 | +0·034 | +23 |
| | +0·051 | +0·034 | +0·052 | +25 |
| | +0·037 | +0·052 | +0·058 | +27 |
| | +0·027 | +0·063 | +0·063 | +29 |
| | +0·026 | +0·061 | +0·083 | +31 |
| | +0·054 | +0·030 | +0·093 | +33 |
| | +0·100 | +0·000 | +0·000 | +35 |
| | +0·087 | +0·000 | +0·000 | +37 |
| | +0·093 | +0·035 | +0·061 | +39 |
| | +0·071 | +0·062 | +0·084 | +41 |
| | +0·050 | +0·085 | +0·086 | +43 |
| | +0·044 | +0·093 | +0·082 | +45 |
| | +0·050 | +0·085 | +0·086 | +47 |
| | +0·071 | +0·062 | +0·084 | +49 |
| | +0·093 | +0·035 | +0·061 | +51 |
| | +0·087 | +0·000 | +0·000 | +53 |

**Table 4**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| ·5*UDL* | +0·022 | +0·000 | +0·000 | +37 |
| | +0·021 | +0·004 | +0·014 | +39 |
| | +0·015 | +0·009 | +0·017 | +41 |
| | +0·008 | +0·013 | +0·015 | +43 |
| | +0·005 | +0·011 | +0·011 | +45 |
| | +0·003 | +0·007 | +0·008 | +47 |
| | +0·003 | +0·004 | +0·005 | +49 |
| | +0·002 | +0·002 | +0·003 | +51 |
| | +0·001 | +0·000 | +0·000 | +53 |

**Table 5**

**Bending Moments on Skew Plate**

| Example No. 1 | *RT* Width to *RT* Span Ratio 2·00 | | Angle 0·0 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| *UDL* | +0·130 | +0·000 | +0·000 | +37 |
| | +0·125 | +0·012 | +0·001 | +39 |
| | +0·124 | +0·016 | +0·000 | +41 |
| | +0·124 | +0·018 | +0·000 | +43 |
| | +0·124 | +0·018 | +0·000 | +45 |
| | +0·124 | +0·018 | +0·000 | +47 |
| | +0·124 | +0·016 | +0·000 | +49 |
| | +0·125 | +0·012 | +0·001 | +51 |
| | +0·130 | +0·000 | +0·000 | +53 |
| *KEL* | +0·258 | +0·000 | +0·000 | +37 |
| | +0·250 | +0·025 | +0·001 | +39 |
| | +0·248 | +0·033 | +0·000 | +41 |
| | +0·248 | +0·036 | +0·000 | +43 |
| | +0·248 | +0·037 | +0·000 | +45 |
| | +0·248 | +0·036 | +0·000 | +47 |
| | +0·248 | +0·033 | +0·000 | +49 |
| | +0·250 | +0·025 | +0·001 | +51 |
| | +0·258 | +0·000 | +0·000 | +53 |

**Table 6**

**Bending Moments on Skew Plate**

| Example No. 23 | *RT* Width to *RT* Span Ratio 1·00 | | Angle 60 | |
|---|---|---|---|---|
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +17 | —0·001 | +0·000 | +0·000 | +1 |
| +17 | —0·002 | +0·001 | +0·000 | +3 |
| +17 | —0·005 | +0·005 | +0·000 | +5 |
| +17 | —0·010 | +0·011 | +0·001 | +7 |
| +17 | —0·017 | +0·023 | +0·003 | +9 |
| +17 | —0·031 | +0·044 | +0·013 | +11 |
| +17 | —0·049 | +0·081 | +0·056 | +13 |
| +17 | —0·030 | +0·122 | +0·249 | +15 |
| +17 | +0·313 | +0·000 | +0·000 | +17 |
| Load at | *Mp* | *Mq* | Angle | *BM* at |
| +17 | +0·000 | —0·001 | +0·000 | +1 |
| +17 | +0·001 | —0·002 | —5·578 | +3 |
| +17 | +0·005 | —0·005 | —2·441 | +5 |
| +17 | +0·012 | —0·010 | —1·956 | +7 |
| +17 | +0·023 | —0·017 | —4·139 | +9 |
| +17 | +0·046 | —0·033 | —9·702 | +11 |
| +17 | +0·101 | —0·069 | —20·381 | +13 |
| +17 | +0·306 | —0·214 | —36·480 | +15 |
| +17 | +0·313 | +0·000 | +0·000 | +17 |
| Load at | *Mx* | *My* | *Mxy* | *BM* at |
| +19 | +0·073 | +0·000 | +0·000 | +1 |
| +19 | +0·307 | —0·085 | +0·021 | +3 |
| +19 | +0·283 | —0·156 | +0·185 | +5 |
| +19 | +0·213 | —0·154 | +0·181 | +7 |
| +19 | +0·139 | —0·118 | +0·141 | +9 |
| +19 | +0·081 | —0·075 | +0·095 | +11 |
| +19 | +0·043 | —0·042 | +0·056 | +13 |
| +19 | +0·024 | —0·020 | +0·029 | +15 |
| +19 | +0·014 | +0·000 | +0·000 | +17 |
| Load at | *Mp* | *Mq* | Angle | *BM* at |
| +19 | +0·073 | +0·000 | +0·000 | +1 |
| +19 | +0·308 | —0·087 | +3·188 | +3 |
| +19 | +0·351 | —0·223 | +20·097 | +5 |
| +19 | +0·287 | —0·228 | +22·250 | +7 |
| +19 | +0·201 | —0·180 | +23·828 | +9 |
| +19 | +0·126 | —0·120 | +25·292 | +11 |
| +19 | +0·071 | —0·070 | +26·337 | +13 |
| +19 | +0·038 | —0·035 | +26·460 | +15 |
| +19 | +0·014 | +0·000 | +0·000 | +17 |

**Table 7**

| No. | Ø | W/S |
|---|---|---|
| 1 | 0 | 2/1 |
| 2 | | 3/2 |
| 3 | | 1/1 |
| 4 | | 3/4 |
| 5 | | 1/2 |
| 6 | 15° | 2/1 |
| 7 | | 3/2 |
| 8 | | 1/1 |
| 9 | | 3/4 |
| 10 | | 1/2 |
| 11 | 30° | 2/1 |
| 12 | | 3/2 |
| 13 | | 1/1 |
| 14 | | 3/4 |
| 15 | | 1/2 |
| 16 | 45° | 2/1 |
| 17 | | 3/2 |
| 18 | | 1/1 |
| 19 | | 3/4 |
| 20 | | 1/2 |
| 21 | 60° | 2/1 |
| 22 | | 3/2 |
| 23 | | 1/1 |
| 24 | | 3/4 |
| 25 | | 1/2 |

**Table 8**

**Bibliography**

1. Jensen, V. P. "Analysis of skew slabs." University of Illinois, Engineering Experiment Station, September 1941 pp. 112, Bulletin Series No. 332.
2. Timoshenko, S., "Theory of Plates and Shells."
3. Robinson, K. E., "The behaviour of simply supported skew bridge slabs under concentrated loads."
4. Morley, L. S. D., Private communication.

**Discussion**

The Council would be glad to consider the publication of correspondence in connexion with the above paper. Communications on this subject intended for publication should be forwarded to reach the Institution by February 28th, 1962.

Note: A copy of the machine output (to 5 decimal places) for Tables 2-7 is available in the Institution's Library.

# Book Reviews

**Progress in Solid Mechanics:** Volume 1, edited by I. N. Sneddon and R. Hill. (Amsterdam: North Holland Publishing Co., 1959) 6 in. × 9 in., 450 pp. 100s.

One of the most troublesome jobs that a research worker has to undertake comes right at the beginning of his project, when he must acquaint himself with the work done by other people on the same problem. This entails a wearisome search and anything that helps to simplify the task is more than welcome. Professors Sneddon and Hill have combined to produce a book that is a particularly good example of what is needed. Under their editorship a group of experts have combined to give up-to-date (1958) reviews of eight lines of research that are developing actively. These are :—

1. The propagation of waves in materials that creep.
2. The use of matrices for vibrating beams.
3. The formation of cavities in ductile metals by explosives, etc.
4. The mathematical legitimacy of plastic collapse and shakedown theories.
5. The dispersion of elastic waves in bars.
6. The effect of temperature on strain and of strain on temperature in an elastic body.
7. Dislocations in crystals.
8. Three-dimensional stress analysis.

The work does not pretend to be a simplified treatise for use by engineers. It is concise and thorough and demands an extensive knowledge of mathematics. It is in fact designed for applied mathematicians who are interested in elasticity and allied topics and who either want to make a start in one of the subjects treated or seek some knowledge of work being done outside but near to their own field.

S. J. McM.

**Atomic Energy Waste: Its Nature, Use and Disposal,** edited by Dr. E. Glueckauf. (London: Butterworths, 1961) 10 in. × 6 in., 420 plus xi pp. 95s

This remarkable book on atomic energy waste, written by a number of experts each a specialist in his own field of activity, and brought together and edited by Dr. E. Glueckauf, is undoubtedly one of the most important and up-to-date documents of its kind.

In the early years of atomic energy, the problem of how to deal with the radioactive waste products was approached with a feeling of apprehension, but their disposal has not proved insurmountable and has, as anticipated, required only a small fraction of the ingenuity that brought such fission products into being.

The confidence with which engineers and scientists currently approach these developments is reflected in this research report. The book deals extensively with the great increase in our knowledge of the waste products, and of how they arise, of their chemical processing and of the effects of their radiations on materials and living organisms. Some contributors concentrate on the large-scale applications of radiation, especially in the fields of food preservation, agricultural applications, and chemical manufacture. Others deal with international legislation on radioactive waste, with aspects of industrial safety, and with the technology and the chemical background of waste disposal.

As each contributor is a known authority on the special subject he has undertaken to report, the book is assured of a place in the essential reading list of all concerned with the varied applications of fission product radiation, as well as those seeking solutions to problems of atomic waste disposal.

A generous list of references, glossary, and subject index are provided.

T. C. W.

**Structural Steelwork Section Book.** 9th Edition. (Glasgow: Fleming Brothers (Structural Engineers) Ltd., 1961) 8½ in. × 5 in., 796 plus xxiv pp. and photographs, 25s.

The new edition of this useful handbook retains the special features of previous editions with the addition of new tables where required. The safe loads for beams, columns, struts and ties have been brought up to date with current British Standards and examples are given to show how the permissible stresses may be obtained.

A large section has been devoted to portal frames and includes scantlings for various spans and heights, formulae to find horizontal thrusts, and the coefficient tables for calculating bending moments have been replaced by a series of graphs which cover single and double spans. An example of design on the plastic method is also included.

Other information included concerns roof truss scantlings for varying spans, plate girders, welding, friction grip bolts, welded, bolted and riveted brackets, stanchion sections for varying building dimensions, fire protection of steelwork, data for various sheets, overhead crane and railway data, mathematical tables, etc.

# The Structural Use of Aerated Concrete *

## Discussion on the Paper by A. Short, M.Sc., J.P., M.I.Struct.E., and W. Kinniburgh, F.R.I.C.

### Corrections and Explanations

Page 6, Col. 1, first paragraph of section on thermal transmittance, after the word 'temperature' insert the words 'of the air.'

Regarding densities, unless the term 'dry density' is expressly used the intended meaning is nominal density. Mr. Kinniburgh said this notional density is often a pound or two different from the dry density, as may be expected.

Thermal conductivity values are assumed to be at normal humidity and temperature, i.e., 65 per cent. humidity and 64° F. Moisture content is usually 5 per cent. or so by weight.

*Figure* 7. Density figures are stated in lb. per sq. in.; instead of lb. per cu. ft.

### Discussion

Mr. SHORT said he understood there was a belief that the permanent deflexion of aerated concrete flexural members under load was much higher than that of reinforced concrete made with dense concrete. This was not so. There was no doubt that under controlled atmospheric humidity and temperature conditions, or in conditions that usually occur inside buildings, the permanent deflexion of reinforced aerated concrete members was considerably smaller than that of dense concrete members having much higher strength. Since these elements are autoclaved, their shrinkage movements were also much less.

Mr. J. W. A. AGER congratulated the authors on the way in which they had packed so much information on this important subject into the small space of 15 pages.

When it was considered that the Rilem International Symposium on steam cured lightweight concrete, held in Gothenburg in June 1960, included 43 separate papers on different aspects of autoclaved aerated concrete, some appreciation of the authors' task in covering the structural use of the material in one paper might be gained.

He commented that in a number of places in the paper, reinforced products were referred to as 'slabs,' 'panels,' 'beams,' or 'units.' For example, in Fig. 13 both the terms 'slab' and 'beam' were used for what were described in the text as 'identical units.' He pleaded, therefore, for a uniform nomenclature and suggested that the following, as used by the major manufacturers, be adopted :—

*Slabs* — reinforced members whose width is several times that of their depth or thickness, and which are usually designed to carry uniformly distributed loading.

*Lintels* — members whose width and depth are much the same and which are usually designed to carry fairly heavy loads.

*Staves* — which, when reinforced, are usually of smaller width than depth or thickness and are usually designed for uniformly distributed loads.

Un-reinforced units were normally used for walling and it was suggested that they be termed 'blocks' when their face dimensions were such that their length was less than three times their height, and 'staves' when their length exceeded three times their height, as laid in the wall.

It was realised, he said, that this notation would not cover all cases, but it would go some way to ensuring uniformity of description.

On page 4, para. 2, it was stated that "Structural reinforced aerated concrete *has* been used at densities between 30 and 40 lb/cu. ft. . . ." In fact, said Mr. Ager, so far as the most widely used reinforced aerated concrete was concerned, over 90 per cent. of the reinforced production was of density 31 lb/cu. ft.; this density was actually the principal structural density used.

On page 13, para. 2, under the heading "Small Dwelling Houses," reference was made to the widespread use of autoclaved reinforced aerated concrete units (mainly slabs) as load bearing walls. He said it should be pointed out that this included external walls and that the standard form of construction was the single skin wall; the thickness of the walls being dictated principally by structural and thermal insulation requirements. This was in contrast to the cavity wall, which was the usual form of brick construction in this country.

On page 14, para. 2, it was stated that "Thermal insulation inside an occupied building is not of great importance and aerated concrete is not a good sound insulator." These two statements needed some qualification.

Thermal insulation inside a building was of importance, for instance, in blocks of flats where the individual flats were heated and metered separately—since obviously one tenant would not wish to pay for heating his neighbour's flat.

The specific sound insulation qualities of aerated concrete might not be outstanding, but it must be remembered that by suitable design of the wall or floor any desired degree of sound insulation could be achieved. This was the case with many other lightweight forms of construction at present used in building.

It should be pointed out, too, that for many applications where the textured surface of the aerated concrete members was not completely obscured by a hard smooth finish, aerated concrete had relatively good acoustic properties.

Next, Mr. Ager drew attention to the reference, on page 6, col. 2, paras. 3 and 4, to problems arising in connexion with the development of reinforced aerated concrete and the urgency of research into them. He drew the authors' attention to the serious implications and limitation of the use of reinforced aerated concrete which could arise from such an unqualified statement. He reminded them that the case was very little different for many of the structural materials we had been accustomed to use for many years. Consider, for example, ordinary dense reinforced concrete. Although we had been using it for over half a century, we still knew very little about its behaviour in shear and tension, when made with various aggregates and when used in certain environments. The periodic revision of our codes of practice and stress/strength ratios indicated

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this. Much the same applied to prestressed concrete and even to steel.

Regarding codes of practice, he agreed with Mr. Short that it was too early for a code of practice to cover the structural use of autoclaved aerated concrete in this country, as it could unnecessarily limit the development and use of the material. Nevertheless, he agreed that the actual work of preparing a code did focus attention on those matters on which further information and research were desirable.

However, he emphasised that, in his opinion, when such a code is drawn up it should, as in the case of those in being or in preparation in Germany and the Scandinavian countries, be quite separate from and not dependent on any codes of practice relating to ordinary reinforced concrete. It would appear that the authors held a similar view, for they had mentioned several times in the paper that autoclaved aerated concrete was quite a different material from ordinary concrete.

Furthermore, he recommended that the code should be mainly one of functional requirements, and based on acceptance tests rather than on a theoretical design method. That this was important was shown clearly by the authors' reference to the different raw materials, methods and techniques adopted by the various manufacturers, all of whom, as the authors had stated on page 12, col. 2, paras. 4 and 6, supplied mainly standard articles with similar structural properties to satisfy similar functional requirements.

Mr. MORRIS T. SHAW (Member of Council) confirmed what Mr. Kinniburgh had said about the strength of aerated concrete, and said that he had first made it in 1924 in the days when aerocrete was sold in bags, the aluminium powder having already been mixed with the portland cement. He had been interested in having structural slabs which would give insulation on the top platform of the retort house in the Belfast Gasworks.

In manufacturing the slabs allowance had to be made in the moulds for the rise of the aerocrete and perhaps the limits of control were not quite so accurate as at present. He was very pleased to see that foaming concretes were going from strength to strength.

He recalled that in the *Irish Builder* in the early twenties a paper was presented which described details of composite construction using aerocrete in long span slabs.

Insulation and structural properties used in those days were as follows :—

**Heat Insulation of Aerocrete Slabs**

B.T.Us/sq. ft/hour/°F diff. of Temp. for various thicknesses.

| Thickness | 3″ | 4″ | 5″ | 6″ |
|---|---|---|---|---|
| Diff. of Temp. °F. | 0·40 | 0·34 | 0·29 | 0·25 |
| Thickness | 7″ | 8″ | 9″ | 10″ |
| Diff. of Temp. °F. | 0·22 | 0·20 | 0·18 | 0·16 |

*Stresses etc.*

| | | | |
|---|---|---|---|
| Tensile Strength | = | 50 | lb/sq. in. |
| Crushing ,, | = | 700 | ,, |
| Bending ,, | = | 1,000 | ,, |

$$\text{Ratio } \frac{\text{Modulus of Elasticity of Steel}}{\text{Modulus of Elasticity of Aerocrete}} = m = 80$$

If the safe stress in the steel is taken at 16,000 lb/sq. in. and the safe stress in the aerocrete is taken at 200 lb/sq. in., the economic ratio of reinforcement will be 0·312%.

An aerocrete beam 12 in. wide will therefore take a bending moment (lb.: in.) equal to $d^2.500$ (where $d$= depth from compression surface of beam to centre of reinforcement).

Mr. D. LAX (Member) illustrated some acceptance tests on an area of roof constructed of aerated concrete slabs.

**Fig. 1.**

Fig. 1. showed three normal slabs each 11 ft. 3 in. long under test, completed as an area of roof 11 ft. 3 in. × 6 ft. 0 in. finished with roofing felt ; the joints were mortar filled without steel and the under side of the slabs was painted with an emulsion paint. The object of this test was to establish the carry over factor of the dovetail joints, of the type shown in Fig. 16 of the authors' paper, by loading the centre slab only and checking the central deflexion against that recorded on the two outer slabs. In addition to slip gauges on the centre of each slab, dial gauges were placed on either side of the joints. A load of 60 lb. per square foot was applied on the centre slab only and the deflexion recorded on this slab was 0·18 inches.

It was interesting to note that the centre deflexion recorded on the centre slab of 0·18 inches compared with that of 0·14 in. previously found for a uniformly distributed load of 20 lb. per sq. ft. over the whole test area and with 0·50 in. for 60 lb. per sq. ft. over the whole area. This indicated that the type of joint used did give a satisfactory carry over, very close to uniform distribution.

Fig. 2. shows the underside of the joint whilst still under load. The washers indicate the position of the dial gauges which were removed for the photograph. The emulsion paint has spanned the joint in globules and as will be seen no visible crack has occurred at these points.

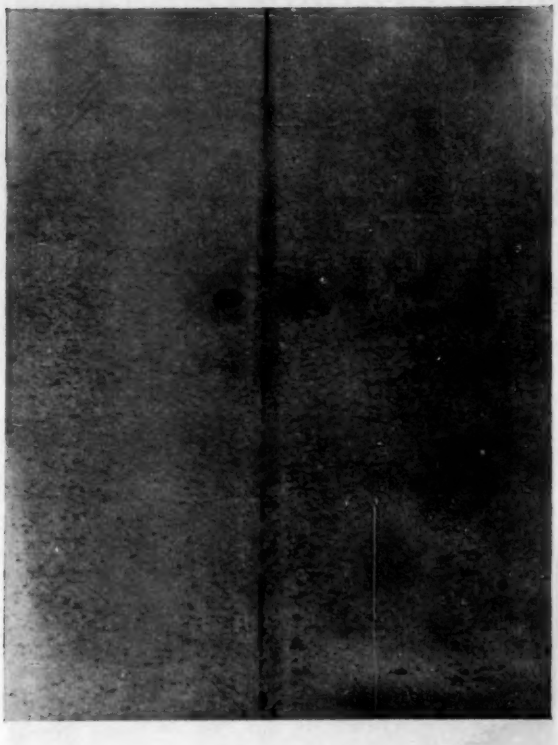

Fig. 2.

To establish the suitability of the aerated material to provide fastenings for cables, conduits, light and other small fittings the rig shown in Fig. 3. was developed. The fastening under test is subjected to a five to one ratio of pull to the weight applied at the tray.

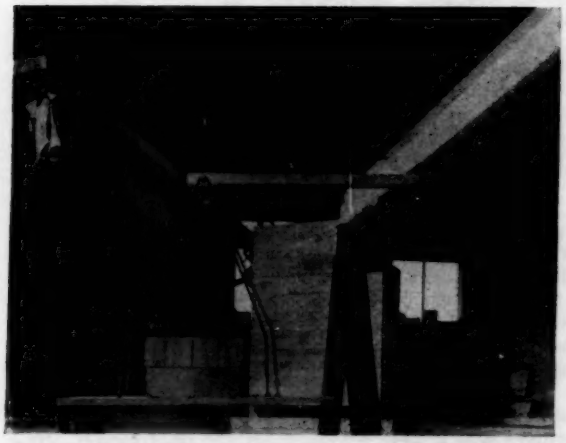

Fig. 3.

**TABLE No. 1.**

| Description | Weight in pounds to pull screw from slab | | | Remarks |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 1½″ : 8 Gauge Wood Screw | 54 | 59 | 64 | Screws driven direct into slab without pre-holing |
| 2″ : 10 Gauge Wood Screw | 145 | 140 | 111 | Screws driven direct into slab without pre-holing |
| 2½″ : 12 Gauge Wood Screw | 164 | 198 | 198 | Screws driven direct into slab without pre-holing |
| 2″ : 10 Gauge Wood Screw Surface of Slabs Plastered ½″ thick. | 154 | 149 | 149 | Plaster spalled off at failure |
| 2½″ : 12 Gauge Wood Screw Surface of Slab Plastered ½″ thick. | 217 | 246 | 204 | Plaster spalled off at failure |
| 3/16″ Recco Type Expanded Bolt Embedded 1¾″ | 121 | 84 | 92 | Driven into Slab not Pre-bored |
| ¼″ Recco Type Expanded Bolt Embedded 1¾″ | 246 | 221 | 174 | Driven into Slab not Pre-bored |
| 3/16″ Recco Type Expanding Bolt Embedded 1¾″ | Small and inconsistent readings. | | | Pre-boring was necessary to fix. |
| All the above Type fastenings in Philplug Filler with Pre-bored Holes. | Very small and inconsistent readings. | | | Not Satisfactory. |

This table shows the results obtained at pull out of the various fastenings stated, but as considerable creep occurred before failure it would be prudent to restrict the working load to 25% of the figures stated until further test results are available. All failures were by shear at the perifery of the screws or fastenings.

The best results were obtained by screwing direct into the material without any preboring. Plugging with the normal type of proprietary compounds was unsatisfactory.

In Fig 4. the surface of the material appears to be friable and would indicate considerable surface dusting. To ascertain the extent of this, a 3,000 frequency vibrator of the screed board type was mounted on top of the rig and vibrated for one hour. Airtight boxes in three sections covering both joints and a plain section of slab were clamped across the area under test. There was a remarkable result.

Fig. 4.

Down the two outer boxes in Fig. 5. there was a line of dark material which was precipitated from the mortar of the dovetail joint, otherwise dusting from the aerated concrete was almost non-existent. Should dusting have occurred this would have been detected visually due to the white colour of the slab compared with the normal cement mortar.

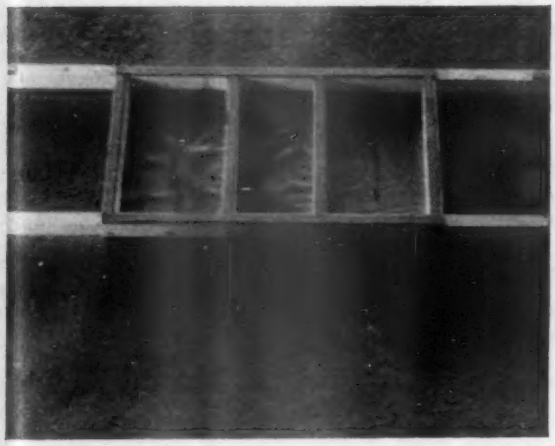

Fig. 5.

Mr. P. H. PRATT (Associate-Member) said that he also had been concerned in carrying out some tests similar to those discussed by Mr. Lax, with whom he agreed on the question of the distribution of loading. In his tests there were three similar units jointed together to form a panel with an effective span of 6 ft. 6 in. They were 4 in. units and were designed to carry a superimposed load of 100 lb/sq. ft. The interesting point was that a 15 cwt. load concentrated on an area of 54 sq. in. in the centre of the panel produced deflexions at the centre point of each unit of 0·172 in. on one outside unit, 0·212 in. on the centre unit, and 0·165 in. on the other outside unit. Since load is proportional to deflexion it may be calculated that, of the 15 cwt., 6¼ cwt. was carried by the centre unit and roughly 4¼ cwt. on each of the outside units, which expressed as a percentage was 85 per cent of a perfect distribution.

Pulling out tests were also carried out, and he agreed that the Plastic type filler in a pre-bored hole was useless. It was found, however, that with the normal fibre rawlplug insert in a pre-bored hole, a 2½ × 10 wood screw gave values of up to 350 lb. whilst $\frac{5}{16}$ in. diameter rawlbolts gave values of only 360-400 lb. As the latter were far the more expensive, and rather than use normal wood screws directly into the under side of the units, which were unreliable, the relatively cheap rawlplug inserts were well worth using.

Mr. J. F. PURVIS (Associate-Member), congratulated the authors on their paper, and said the company with which he was associated commenced production of aerated concrete blocks in 1951. These blocks were made to a dry density of 50 lb/cu. ft. the formula being developed in the laboratories of the parent Company. The blocks met the requirements of the British Standard 2028 Type ' B,' which requires a minimum saturated block compressive strength of 400 lb/sq. in. and a drying shrinkage of 0·06 per cent.

In 1954 a technical association was arranged with a Swedish company, to enable them amongst other things to obtain machinery and erection ' know-how ' for reinforced units. For these units, they were using a modified form of the original formula, giving dry densities of 30 and 40 lb/cu. ft. He particularly mentioned the density as being dry for the authors gave a figure of moisture content which might initially be up to 25 per cent heavier than the dry density. Mr. Purvis expressed the opinion that with certain aerated concretes, this figure could be as high as 40 per cent, although immediately after autoclaving his company's material gave about 20 per cent, and even less for blocks.

The basic materials used were cement, sand and pulverised fuel ash, none of which required grinding. Aeration was basically by the aluminium powder/hydrogen gas method, the final product being durable, inert and non-aggressive.

**Some Structural Characteristics** (see page 6.)

*General*

The remarks under this heading were such that the impression might be gained that manufacturers were putting these products on the market before all the problems connected with them were solved. If this impression had been created, Mr. Purvis would like to correct it, for even prestressed concrete and reinforced concrete had still not solved all their problems and that had not prevented these materials being used in large quantities.

**Corrosion Protection** (see page 6.)

Tests described in the Paper of a large number of samples exposed at Beckton Gas Works, over a period of two years, were the result of his company's experimenting with various protective treatments. These independent tests were conducted to help decide the best material to be used by them. The material which proved most satisfactory was a proprietary bitumen compound that had been developed by a German company and had been used in Germany for a considerable number of years. It complied with the rather stringent requirements DIN.4223, the German Code of Practice for Cellular Concrete Units. The Code required a salt test to be conducted, which consisted of

dipping the protected bars in a solution of 3 per cent by weight of common salt and water ; after being immersed for the required period a visual inspection was conducted.

**Bond and Anchorage** (see page 9.)

Mr. Purvis then referred to the authors' statement that bitumen solutions of various kinds are usually satisfactory, but in most cases lead to unreliable bond properties. The proprietary bitumen compound which his company were using provided good bond properties when the units were carrying their design load and at least three-quarters of this load were transferred to the steel by direct bond. If the loading was increased beyond this design load, to say twice the design load and over, and when it gradually reached ultimate load conditions the protective coating provided less bond. In production, droplets tended to form along the surface of the bars creating corrugations similar to that mentioned in cement coatings. At present in design, therefore, they assumed that anchorage was obtained solely by the cross-bars being welded to the longitudinal bars.

**Load Factors Against Cracking and Failure** (see page 11.)

The authors' statement that a generally accepted method of design did not exist might be taken in the wrong manner, and also the remark that the manufacturers' designs were preliminary. Both in this country and on the Continent these units were designed either to the classical elastic theory or the load factor method of design, and they were as much in keeping with it as normal reinforced concrete. Design calculations based on the elastic theory had already been submitted to local authorities in this country and had been approved by them. So far, they had worked to a maximum deflexion under working load of 1/1400 of span, as had their Swedish associates.

**Design Considerations** (see page 11.)

*Shear Strength.*

Mr. Purvis agreed with the authors that where lintels were used it would be necessary to design them in such a manner that the internal shear forces were wholly resisted by the reinforcement. He did not, however, agree with their last remarks under this heading. Other units had no difficulty in resisting the shear forces without the steel being taken into account.

**Workmanship** (see page 12.)

Mr. Purvis continued his remarks in a further written discussion. He agreed with the authors' earlier statement that very rigid control was necessary in the manufacture of this product and the testing and quality control in the factory had, in his experience, a much higher standard than that found on the normal building site. In the case of sites, his company was at the present time erecting all the material it was producing, to make sure that the site work was carried out in the prescribed manner.

Closing his remarks on design considerations, he drew the following comparisons :—

In in-situ concrete one group of people (the Consultants) did the design calculations, the drawings, while the other (the Contractor) did the manufacture and construction. In Scandinavia the generally accepted practice for precast concrete, a mass fabricated product, was that the Consultant need only know which product had the qualities he desired to use, i.e., weight of the material, its durability, and whether its general properties such as stiffness span and depth ratio were sufficient for his purposes. The calculations and the manufacturing and erection were usually beyond his detailed interest, and Mr. Purvis thought this might be the reason why the authors felt that certain answers to what they considered were important problems were not readily available for public use.

Mr. T. G. W. BOXALL referred to the excessive moisture movement of cast-in-situ aerated concrete used for the insulation of the roofs of Newsprint paper mills in Canada in 1926. He presumed that this disadvantage had at least partially been overcome in the case of the pre-cast materials that had been described by the authors.

He noted that Mr. Kinniburgh had stated that the thermal conductivity values, quoted in the paper, were those obtained under conditions of normal humidity and temperature, i.e. at 65 per cent humidity and 64° F. Mr. Boxall had not had an opportunity to read the paper, but he wondered if this statement meant that any thermal transmittance figures given in the paper, had been based on calculation. He hoped that this was not so, because he was sure that after many years' experience of measuring thermal transmission through walls exposed to normal weather conditions, the Building Research Station must have some very interesting ' U '-value figures, and he would welcome any information the authors could give him on this.

Mr. J. R. PHOENIX said that his experience over the last four years had been confined to the structural applications and design of autoclaved aerated concrete and that he would like to confine his comments and questions to that section of the paper.

Turning to the last paragraph under the heading ' Properties ' on page 4, it was stated in the paper that larger sections might sometimes be required in autoclaved aerated concrete in order to obtain the necessary rigidity and strength. Aerated slabs could in fact be designed up to 20 ft. span, with span/depth ratios of 30 for roof loading. This was the maximum figure allowed in C.P.114 for R.C. slabs. For heavier loadings thicker slabs were required, for example, 75 lb/sq. ft. superimposed loading could be taken on slabs up to 20 ft. with a span/depth ratio of 24 for all but the shortest spans. The deflexions in these cases were similar to those obtained with reinforced concrete. These ratios compare very favourably with reinforced concrete.

Mr. Phoenix said that in his reading of the section headed ' Durability ', on page 8, he gathered that a number of autoclaved lightweight beams were exposed with an imposed load of twice their design load in an atmosphere rich in sulphur at Beckton. However, the effect of this exposure and loading was reported for one of those beams only and a deflexion/time curve was given for this one beam which showed that it failed after 9 months exposure. It would be of considerable interest if the authors could give more information of the behaviour of the other beams so tested. To assist in obtaining a broader evaluation of this type of material exposed in polluted atmospheres the following information would be of assistance :—

How many beams were exposed with twice their design load at Beckton ?
Were they roof or floor beams, and what was their designed superimposed loading ?
After what period of exposure did the slabs not reported in the paper fail ?

If they had not yet failed what was the length of the period of exposure to date?

In the first paragraph on page 11 the impression might be given that there was something rather esoteric about the design methods employed by manufacturers of aerated concrete. Mr. Phoenix said that his company designed units by the elastic theory and experimental work had shown that this method corresponded closely with the test results.

In the third paragraph of the section headed "Design of Flexural Members" it was stated that "It is desirable to restrict deflexions by adopting maximum permissible span/depth ratios for various types of structures." This, in Mr. Phoenix's view would be a wholly retrograde step. It was true that span/depth ratios were employed in C.P.114 to govern deflexion, but this was surely employed in the case of reinforced concrete as an attempt to achieve design simplicity. The results obtained by this method were often quite anomalous, deflexions being governed by more considerations than merely depth and span. There was, no doubt, a certain utility in adopting span/ratio limitations in the case of reinforced concrete, but in the case of autoclaved aerated slabs where a small roofing job might employ up to 300 identical slabs a case could be made for the adoption of a more precise and economic design method to deal with the deflexion. He would suggest an acceptance deflexion based on acceptance tests on the lines of the A.C.I. Code for Precast Concrete.

Mr. Phoenix said that in tests carried out by his company it had been found that the actual deflexion was always between 65 per cent and 85 per cent of the calculated deflexion. It was noted that the percentage difference between calculated and actual deflexion depended upon the percentage steel content, the lightly reinforced slabs producing a greater disparity between the calculated and actual deflexions. It had been concluded that this was due to the tensile strength of the material which was not taken into account in the calculation of the deflexion.

As this behaviour was apparent up to almost twice working load Mr. Phoenix said that he would support the authors' proposal in the last paragraph on page 11 where he stated that deflexion might be calculated on the assumption that the concrete section was uncracked. However, if deflexion by calculation was recommended, as the authors' statement would seem to imply, it was not consistent with the statement made earlier on the same page that deflexions should be governed by span/depth ratios.

Mr. Phoenix mentioned that it was further stated on this page that ". . . it may be preferable however to rule that the entire force in the bars should be resisted by anchorage forces for all types of surface treatment." He asked whether this conclusion was drawn from tests on the same material as the conclusion that deflexions be calculated on the assumption that the concrete section was uncracked.

Mr. Phoenix suggested that if it was necessary to take the entire force in the bars by anchorages because bond was unreliable or non-existent it would be unwise to calculate deflexions on the uncracked section.

It is well known that the cracking characteristics of a non-bonded prestressed beam were not as good as the same beam bonded. Mr. Phoenix asked whether the authors had any experimental evidence that a non-bonded autoclaved beam behaved as well from the cracking viewpoint as the same beam bonded over the normal range of spans and loadings notwithstanding the greater strain of rupture of autoclaved concrete. Unless this be so he would suggest that deflexions may only be calculated on the assumption that the concrete section is uncracked in cases where the bond between the steel and the concrete is reliable.

In these considerations Mr. Phoenix said that he was making the normal assumptions that the other variables were fixed, i.e. span, loading, thickness, steel stress etc., and that the point in question was the difference in behaviour of a bonded and a non-bonded beam.

He then referred to the section headed "Shear Strength" on page 11, where it was reported that "A number of specimen beams tested at the Building Research Station failed in shear, particularly after being subjected to prolonged loading under exposed conditions." In his experience he said that shear failures although always giving a factor of safety greater than two were normally confined to short heavily loaded spans: by that he meant to say, for example, a six foot span designed to carry a superimposed load of 80 lb/sq. ft. Mr. Phoenix then said that he would be most interested if the authors could let him have some further information on the slabs which failed in shear when tested at Garston, and that he would be most interested in the span, thicknesses and loadings in which shear failures occurred and also some details of the number and type of slabs to date which failed in shear after prolonged exposure.

Mr. W. HUNTER ROSE (Member), said he would be failing in his duty as Chairman of the Code of Practice Committee, C.P.: 116, "The Structural Use of Precast Concrete," if he did not say how grateful the members of that Committee were to the Director of Building Research and to Mr. Short and Mr. Kinniburgh, for giving us so much information about aerated concrete at short notice.

Whilst, as mentioned in the paper, this material had been in use extensively on the continent for many years we were, in this country, only just beginning to think about it. A previous speaker had mentioned aerocrete. He recalled that as far back as 1930, aerocrete had been used extensively in connection with a very large structure in the North, in which the late Mr. Travers Morgan was interested. This material was aerated concrete but without being autoclaved and the result was disastrous, due to shrinkage. It was important to realise that the material which the authors were talking about, due to the autoclaving, was quite different from 'aerocrete' and, in fact, as Mr. Kinniburgh had pointed out, quite different from normal portland cement concrete as we understood it. This was something we must bear in mind all the time we were thinking about it.

Mr. Hunter Rose questioned the authors concerning the time at which corrosion of the steel took place in reinforced structural units. Did this, in fact, occur in the autoclave, and was this the reason why the steel must be protected rather than the concrete unit as a whole being protected by impregnation or a protective film on the surface of the unit? It was essential to know when corrosion commenced for a fundamental understanding of the question. Could the authors give us their ideas on the mechanics of corrosion in this particular case? Again, suppose there was inadequate protection of the steel and corrosion took place in the autoclave, would the corrosion cease when the unit had dried out, or would it be progressive?

Mr. W. FERGUSON said that his company had started a series of tests on the frameless, loadbearing type of

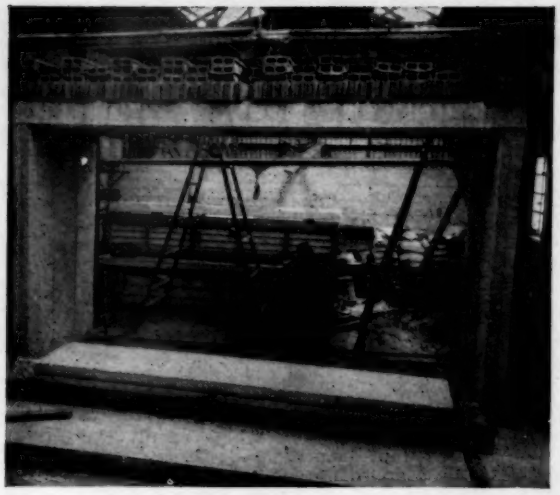

**Fig. 6.**

structure referred to in the third paragraph of page 12, and preliminary results indicated that such structures were certainly feasible.

He said that the first test was on a single storey, single bay portal frame (see Fig. 6) constructed of six vertical wall slabs and three floor slabs. The wall slabs were 10 in. thick, 24 in. wide and 10 ft. 3 in. high, the floor slabs were 12 in. thick, 24 in. wide and 20 ft. 5 in. long. The wall slabs were bedded in mortar and a 2 ft. long $\frac{3}{8}$ in. diameter bar was embedded into a pocket 6 in. deep in the floor leaving 1 ft. 6 in. protruding into the groove between wall slabs — this formed the joint at the bottom of the slabs. The floor slabs were laid on a mortar bed on top of the wall slabs, and the joint formed by embedding one arm of a 6 ft. long $\frac{3}{8}$ in. diameter L shaped bar in the grouted groove between wall slabs, the other arm extending into the groove between floor slabs which was then grouted.

The structure was loaded vertically and a horizontal load applied at the top of the wall to simulate wind loading. The vertical and horizontal loads were increased in increments until the vertical load was equal to the design load of 100 lb/sq. ft., the horizontal load was then further increased until cracking appeared which occurred at the base of one wall. The structure continued to hold the load after cracking.

Analysis of the results indicated that for a two storey building the factor of safety against cracking due to wind load to the worst exposure in C.P.3, Chapter V would be 4·5 with the structure also loaded to its design load vertically. The horizontal deflexion between storeys would be about $\frac{1}{16}$ in. at working load.

Mr. Ferguson then illustrated a number of buildings in the United Kingdom which included aerated concrete components.

Fig. 7 shows a warehouse in East London in which aerated concrete wall cladding and roofing was used. The 14 ft. long 6 in. thick roof slabs were laid on the flanges of the precast beams and the 5 in. thick horizontal wall slabs span between columns at ·15 ft. and 16 ft. 8 in. centres.

Fig. 8 is of the same warehouse and shows a roof slab being lifted into place with a special grab.

Fig. 9 shows part of the roof of a factory in Hertfordshire. The slabs are 10 ft. long, 4 in. thick and the total area of roof is 5,500 sq. yds.

**Fig. 7.**

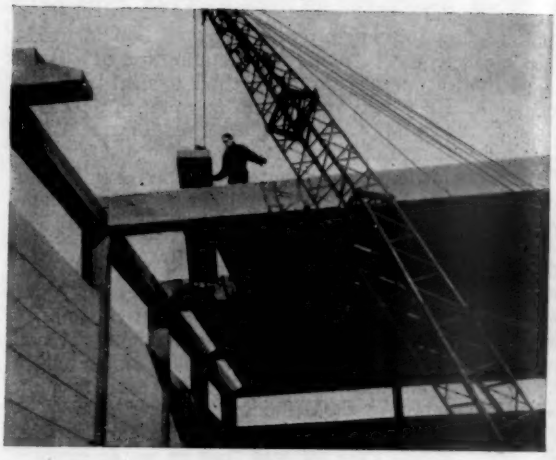

**Fig. 8.**

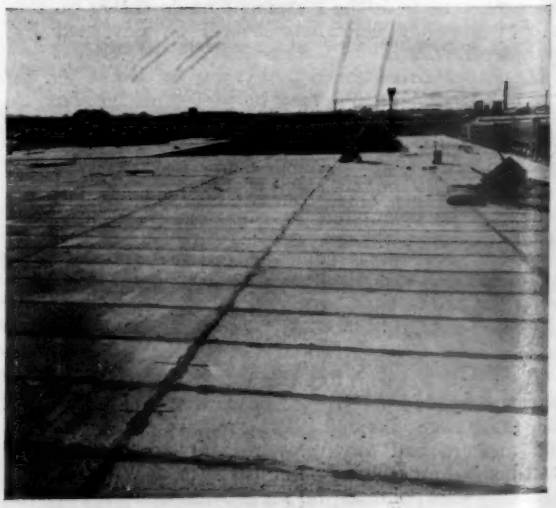

**Fig. 9.**

**Fig. 10.**

**Fig. 11.**

**Fig. 12.**

The use of vertical wall slabs can be seen in Fig. 10 which shows the first of a series of standard factories in a new Scottish industrial estate. The wall slabs are 6 in. thick and span between steelwork at 6 ft. to 12 ft. centres.

Fig. 11 shows a church near Edinburgh. The building has a precast concrete frame—the aerated concrete components include 8 in. blockwork, 5 in. thick roof slabs, 6 in. thick floor slabs and 8 in. thick horizontal wall slabs.

Fig 12 is of the same church and shows 8 in. thick vertical wall slabs 17 ft. long.

Mr. G. E. BESSEY, who said he had been much concerned in earlier years with research on this class of material, emphasised that if aerated concrete were to be used increasingly we must pay a great deal of attention to the material in the coming years. It had been a long time coming, but everybody must now realise its potential.

Whilst he did not detract from the importance of the part which our friends abroad had played in developing this material, he reminded the meeting that one process developed in this country was in operation here, and one speaker had already mentioned it in the discussion ; another British process was the only one effectively operating at the present time in the U.S.A. It was well to remember that we in this country had done something with regard to aerated concrete.

It had been suggested that the first commercial use of this material was in 1929 ; he believed that 1923 or 1924 was historically more correct.

With regard to use in polluted atmospheres, he asked if the authors had looked into the differences in the effects upon different aerated concretes. He would expect the cement bonded material to be less resistant to sulphur gases than a lime bonded one.

If the bonding material were entirely of calcium silicate, one would not expect any expansive effect.

Mr. BÅVE expressed his thanks, as a foreigner, for the opportunity to speak at a meeting of the Institution of Structural Engineers and to comment on this very interesting paper.

He referred to page 4 where it was stated that the lighter densities of aerated concrete were used for thermal insulation only. In fact, 25 lb/cu. ft. density was accepted in the Swedish specifications for loadbearing walls. The 31 lb/cu. ft. was no doubt the most used for reinforced slabs. However, 25 lb/cu. ft. density was being successfully used in Sweden and Canada for roofing slabs.

Mr. Båve then referred to page 5 where it was stated that long term tests on creep had been carried out at the Building Research Station and said that he assumed that these tests referred to the result given in Fig. 13 and named " Beam Tested in the Laboratory."

In order to compare the results obtained at B.R.S. and the ones given in his paper to the RILEM Symposium on Steam Cured Cellular Concrete Mr. Båve had plotted the results obtained on an aerated slab and on a dense concrete slab by Washa and Fluck on the same graph as the results as given in Fig. 13 of the paper (see graph).

It was interesting to see how close the slab tested by Nylander followed the curve of the Beckton slab while the dense concrete slab tested by Washa and Fluck showed a greater increase in deflexion than both of these slabs. The tests carried out by Nylander carried the design load while the Beckton slab had twice the design load.

The results obtained at Beckton showed quite a normal creep deflexion. On the other hand the result of the slab tested in the laboratory gave what Mr. Båve considered an unusually low creep and he would be grateful to hear the author's opinion of these viewpoints.

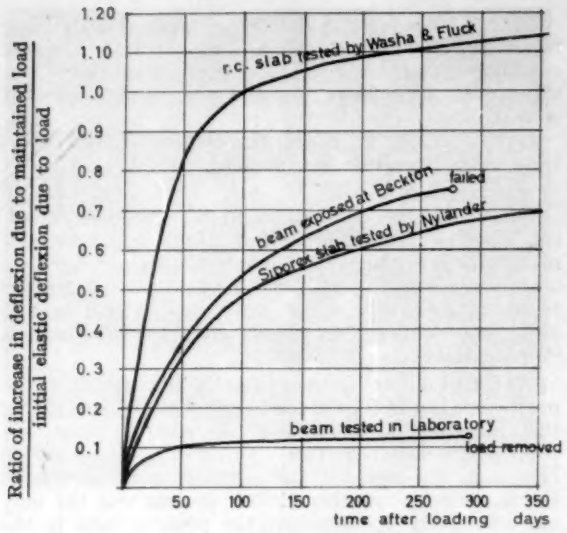


**Fig. 13—Comparative deflexion of aerated and normal concrete slabs under sustained loading**

Mr. Båve referred to what was said about rain penetration on page 5 of the paper. A large amount of practical experience on the behaviour of cellular concrete walls was also available from other countries having a climate more similar to the British Isles than Sweden had. Single skin block walls or wall slabs were extensively used in Denmark, Western Germany and Belgium, in some cases without rendering, showing low moisture contents. In unusual cases where such high moisture contents as 40 per cent had been observed the explanation was generally to be found in a fault in the construction, such as bad detailing.

The authors said that the bond strength of bars dipped in cement latex mixture was higher than that of smooth bitumen covered bars. Mr. Båve thought it was of interest to note that tests showed an increase of the bond strength for cement latex coated bars of 15-20 per cent compared to the bond of unprotected smooth bars. Thus there was no reduction of the bond when using cement latex coating as the authors stated on page 7 under methods of protection.

The fact was that very high bond strength in relation to the compressive strengths of the material was obtained with cement latex coating as the authors also had mentioned on page 9. Results on pull out tests varied from 150-220 lb/sq. in. These values gave a ratio of the compressive strength that corresponded to what could be obtained with deformed bars in dense concrete.

In view of the fact that the bond characteristics varied widely with various kinds of cellular concrete and protective coatings it seemed logical not to give a calculation method for the anchorage but instead follow the same way the Scandinavian standards suggested and ask for acceptance tests.

The safety factor of the beams tested at the Building Research Station and described on page 11 under "Load factors against cracking and failure" might appear rather high.

The slabs were of Swedish origin and some explanations was needed. The steel quality used had a minimum required yield stress of 37,000 lb/sq. in. However, in practice the yield stress frequently amounted to more than 50,000 lb/sq. in. This would influence the ultimate load as failure occurred as a result of yield of the tensile steel.

The measured steel stresses mentioned also appeared to be low. It was a well known fact from dense concrete slabs that measured stresses were lower than the calculated ones at working load because the tensile zone was not cracked to the same extent as assumed in the calculation. In this case the cracking occurred at a load far beyond the working load.

On page 8 the authors claimed that the exposure of slabs in a polluted atmosphere for nine months would reduce their carrying capacity considerably.

Although the studies made in Sweden of the influence of exposure only included a fairly small number of test slabs Mr. Båve thought it would be of interest to compare the results with that obtained at the Building Research Station.

Five slabs were tested after exposure of three to five years to the weather in the Stockholm area. In spite of this and the fact that the slabs showed a moisture content of more than 40 per cent by weight when they were tested no reduction of the bending strength was observed.

The atmosphere in Stockholm was clean compared to the London atmosphere. Aerated concrete had however been used for many years in other areas with heavily polluted atmosphere and tests were at present being carried out in the Ruhr in Germany. The average content of $SO_2$ in the Ruhr area was about twice the value registered in London for 1951 and nearly the same as London had as an average in 1952, when the very severe smogs occurred.

So far only two slabs had been tested of this series after five months of exposure in the Ruhr. Although they had been exposed for half the time of the Beckton slab they both showed an ultimate load higher than the identical slabs tested immediately after manufacture.

The authors mentioned on page 12 that a steel bar was inserted in the cement mortar grouted joint between roof and floor slabs to improve the continuity and stiffness. This bar had usually a length of about a third of the span and was embedded in the joint mortar over the support, thus connecting the slabs of two adjacent bays. This continuity was advantageous to protect the roofing felt from large local strains along the supports of the slab. However, it was not taken into account when calculating the deflexion or loading capacity of the slabs.

Mr. A. HILLERBORG referred to the authors' comments on the investigation carried out on aerated concrete roof slabs in Swedish steelworks. The increase in deflexion after two years was in fact so small that it could hardly be measured, and the sulphur content of the atmosphere could be estimated to be at least ten times that at the Beckton exposure site. It would therefore seem unlikely that the slab at Beckton should have failed after nine months due to such an effect, even though the wet conditions of the slab must be regarded as having been more severe.

On page 11, when discussing shear strength the authors differentiated between separate slabs and slabs joined together, suggesting that the provision of shear reinforcement should depend on the number of slabs joined together. There did not appear to be any logical reason to assume, nor any empirical evidence to indicate that the permissible shear load of an individual slab should be at all different from that of one slab in a number joined together. The need for reinforcement should surely depend solely on the calculated shear stress.

At the end of the paragraph on "Design Bases" on page 11, the authors stated that it was desirable to adopt maximum span/depth ratios. Mr. Hillerborg said that it should be noted that the same figure could prove too high in certain cases and too low in others depending on the amount of reinforcement in the slab and the type of slab considered. He said that the use of span/depth ratios was fully considered in Sweden for dense concrete slabs and that it was found to be impossible to allocate figures for such ratios in a logical manner. It was therefore decided not to fix any such figures rather than base a specification on guesswork or figures chosen at random.

In the last paragraph on "Wall, Floor and Roof Units," it was suggested that there was an absence of test results and experience in the use of frameless load-bearing cross-wall structures. Mr. Hillerborg pointed out that the membrane action of reinforced aerated concrete slabs had been studied theoretically and empirically by Nylander in Sweden before 1946 and his results used in the design of saw-tooth roofs. Also, Svedin gave a paper at the Rilem Symposium on the membrane action of roof slabs of aerated concrete.

Mr. KINNIBURGH commented on a number of matters raised in the discussion. With reference to the statement in the paper that "Structural reinforced aerated concrete had been used at densities between 30 and 40 lb/cu. ft.," he said he was ready to accept Mr. Ager's remark that by far the bulk of the reinforced production was of density 31 lb/cu. ft. However, some of the production was at a density of 34 lb/cu. ft. and also at 37 lb/cu. ft., so that the original statement was still true. Although the past tense was used in this statement, it was not intended to imply that the use of reinforced aerated concrete in this density range had been discontinued; the material had been used for many years and was still being used.

In reply to Mr. T. G. W. Boxall, he stated that because of their general application, conductivity or *k*-values were given, and these had been obtained by measurement. Although experimental values had been obtained for thermal transmittance or *U*-values, these had not been quoted, mainly because such values have reference to specific wall arrangements tested under specific exposure conditions and these when used out of context can be misleading. He invited Mr. A. W. Pratt, as a specialist on thermal measurement, to comment on the conditions of testing thermal conductivity.

Mr. A. W. PRATT (Building Research Station) in reply to Mr. Kinniburgh said that the water content of the specimen was important in conductivity tests but there was no universally agreed procedure for specifying it. In Britain official tests were carried out according to B.S.874 but the Standard made no reference to the conditioning or moisture content of specimens. Unless the specimen was initially in a bone-dry condition (which appeared to be standard procedure in American testing) the content and distribution of moisture might be very different at the beginning and end of the test. In these circumstances interpretation of conductivity values *vs* moisture content, particularly in relation to the initial state of the specimen, was extremely difficult and, at the present time, not understood.

For information the Building Research Station method of test was described by Pratt and Ball (1956).[2]

Mr. KINNIBURGH, referring to a comment by Mr. G. E. Bessey on the effect of chemical composition on the resistance to attack by polluted atmosphere, said that there had as yet been no opportunity to compare the resistance of aerated concrete of different composition when exposed to polluted atmosphere.

The point having been made by Mr. Båve that aerated concrete of 25 lb/cu. ft. density was now accepted in the Swedish specifications for load-bearing walls, Mr. Kinniburgh said that this was important information, but according to the latest information at the time the paper was written, the 25 lb/cu. ft. material was reserved for insulation purposes, and the products of density above 30 lb/cu. ft. was used for load-bearing purposes.

Mr. SHORT said that all the questions raised in the discussion had been very helpful indeed; but for the time being, in view of the shortness of the time that was available, he could deal with a few controversial matters only.

On the question of corrosion, raised by Mr. Hunter Rose, it had been found that bars embedded in aerated concrete without adequate protective surface treatment would start rusting in the autoclave. Once started, rusting was likely to continue and spread if the member concerned were exposed to humid conditions. Protective treatments enveloping the entire member, rather than the embedded bars only, would be probably expensive and it would be difficult to prevent mechanical damage and cracking leading to penetration of corrosive substances.

Mr. Phoenix and Mr. Båve mentioned the performance of the slabs exposed and loaded in the open, at Beckton. Mr. Short said that two floor members and one roof member had been exposed under load and identical members were also exposed without any imposed loading. One floor member failed in shear after nine months at the site and the other identical member that had been left without loading on the site also failed at approximately the same load during a test in the laboratory. The remaining elements are still whole and have not failed. The cross section of the latter was such that failure under loading was likely to occur in bending rather than in shear.

Regarding the deflexion of aerated concrete members, the stiffness of such members might be controlled by calculation or by tests and it was for the engineers and manufacturers to come to some agreement on which they preferred. The permissible maximum span/depth ratio method used in C.P.114 was a simplified design method. It was well known that for reinforced concrete this method had major disadvantages, particularly where different types of steel and cross sections were used. For aerated concrete most of these disadvantages would be, in the authors' view, reduced considerably because of the limitations imposed by the method of manufacture and design and the type of steel used.

The permanent deformations measured on different dense and aerated concrete slabs under different conditions would largely depend on the particular types of members and cross section used. What would be of interest was a comparison of the relative size of the permanent deflexions under normal, protected conditions and when exposed to the weather.

The permanent deflexion of the aerated concrete roof slabs in a steel works in Sweden, which was mentioned by Mr. Hillerborg, was apparently severe enough after three years for these slabs to be replaced by new slabs provided with adequate surface protection on the underside. Conditions at Beckton would be more severe however, due to weathering.

It should be emphasized that under controlled conditions the permanent deformation of aerated concrete members under load was much less than that of similar dense or lightweight aggregate concrete beams.

The bond strength of bars embedded in aerated concrete suffered because of the likelihood of cavities along them, formed as a result of the 'shadow effect.' The incidence of this effect could be reduced considerably in the factory but cannot be entirely eliminated with any degree of certainty. Adequate anchorage would therefore, in his view, be necessary, although the bond strength of bars covered with cement-rubber coating or some types of bituminous coating would probably ensure combined action between steel and concrete in most cases.

On the question of shear Mr. Short felt that because of its sudden nature, failure in shear must be guarded against even more strenuously than against failure of the tension reinforcement, which usually would result in large deformation rather than in immediate collapse.

It was known that the effect of shear stresses in isotropic or slightly anisotropic slabs is less serious than in separate beams. Shear reinforcement is not therefore normally necessary in slabs. In his view reinforced concrete beams, as distinct from slabs, should always contain shear reinforcement, where they are used as major structural components.

In conclusion, Mr. Short expressed the authors' indebtedness to those who spoke in the discussion for their most able and interesting contributions, to the President and to the Institution, and to the gentlemen who listened to the presentation of the paper.

THE PRESIDENT apologised to those present who would have liked to have taken part in the discussion, but were unable to do so because of the limitation of time. He invited them to make written contributions, and commented that the published discussion would be as worth while as the paper itself.

And in conclusion he thanked the authors on behalf of the meeting for having so ably dealt with a complex subject in a very short time, and for their replies to the discussion.

### Written Discussion

Mr. K. W. FULLER commented that under the heading "Compressive Strength," Page 4, it was stated that "specimens tested in the saturated condition may reach only 80 per cent of the strength on the same concrete when tested dry." His experience was that this difference might be as great as 70 per cent, but it was known that differences in results would be influenced by the method of drying.

Again under "Compressive Strength," the authors stated that aerated concrete with a density of 35 lb/cu.ft. and over could be expected to have a compressive strength of at least 400 lb/sq. in. It should be pointed out that whereas the 400 lb/sq. in. appeared to refer to a compressive strength test on saturated blocks, 35 lb/cu. ft. density appeared to refer to a nominally dry product.

Under "Thermal Insulation," Page 5, some figures shown in Table 2 on Page 6, quoted equilibrium dry aerated concrete at 50 lb/cu. ft. having a thermal conductivity $k$ of 1·55. He felt that this figure was not necessarily typical for aerated concretes of 50 lb/cu. ft. and would suggest, that the figure quoted in the latest issue of the Institution of Heating and Ventilating Engineers "Guide to Current Practice 1959" namely 1·4, with specimen conditioned in atmosphere of 64° F. and 65 per cent relative humidity, was more applicable.

He suggested that consideration be given as soon as possible to the preparation of an independent guide to good practice, such as a Code of Practice and/or a British Standard which could be used as independent terms of reference by the user. His company would be pleased to co-operate with any committee which might be formed for this purpose. Alternatively, if the preparation of such documents should take too long to be of value in the foreseeable future, then perhaps the Building Research Station could be persuaded to prepare an interim report in collaboration with structural engineers, manufacturers and so on.

In thinking of the preparation of a Code of Practice, the following salient points might possibly be considered:

1. Minimum strength as related to densities.
2. Methods of testing.
3. Methods by which the profession can be satisfied on structural properties either by calculations based on the elastic or ultimate load theory, or by physical tests on the material and the issue of test certificates.
4. Methods for testing the merits of corrosion protection material.
5. Reference to suggested best building practices for each type of unit, for instance, bearing area for roofing slabs, weather protection and so on.

Mr. MICHAEL ADAMS commented that on Page 2 the nature of cellular concrete was discussed and was said to be "functionally a concrete but very dissimilar in its composition and could be more appropriately regarded as an aerated mortar, or aerated sand/lime product." This paragraph went on to suggest that a more descriptive name would be "cellular silicate" or "aerated silicate." Mr. Adams agreed that this was probably correct, but in order to avoid misunderstanding as to the properties of cellular concrete, the words of Bengt Lundgren describing cellular concrete would be worthy of mention. Speaking to the National Concrete Association of America he had said:

"In normal dense concrete the cement acts as a paste or binder, but in steam cured cell concrete the sand/cement/fly ash form a calcium monosilicate which has several times the strength of normal concrete and its physical properties are completely different" * which made it clear that though different from dense concrete it claimed the attention of concrete designers.

He suggested that the thermal conductivity values on Page 11, Table 2 were out of all proportion to the normally accepted figures and referred to the handbook *Thermal Insulation of Buildings* issued by the Building Research Station in 1955, where on Page 48 under Concrete: Aerated: the coefficient of thermal coriductivity, 30 lb. cu. ft. density material was 0·75 BTU/sq. ft/hr/°F/1 in. thickness which seemed rather high for this low density.

In Table 2 of the present paper, the coefficient was 0·95 BTU/sq. ft/hr/°F/in. thickness for 30 lb. cu. ft. density aerated concrete and this seemed almost incredible. The higher densities quoted were more in line with what one would expect though again a little high.

Mr. Adams felt there was a need for a 'safe and logical design theory' mentioned on Page 12. As a manufacturer he found from experience that the elastic theory, plus consideration of functional requirements, would, with the aid of arithmetic, produce design calculations to satisfy the strictest of supervising authorities besides giving the client an economical design.

The first design calculations of his company were accepted by the L.C.C. in 1956. These were prepared in accordance with the principles set out in C.P.114 and

* This was reprinted in the *Indian Concrete Journal* 15th May, 1953.

accepting the limits on working stresses set by the Council's Structural Engineer.

In the circumstances he suggested that more urgent basic problems should claim the attention of our research workers.

Finally, on Page 25 there was a note concerning the construction of roofs in industrial buildings, based on a survey of such buildings, and where conditions were particularly unfavourable it was said that deterioration could be prevented by suitable surface treatment and ventilation of the roof space. Would not these measures be relatively unavailing unless the roof structure were also ventilated so that all moisture had a means of escaping through the top surface immediately above the waterproof covering.

Mr. C. HOBBS referred to the importance given in the paper to the subject of corrosion of reinforcement in aerated concrete and to various treatments used to protect the reinforcement. Mr. Hunter Rose had also asked about corrosion of the reinforcement during autoclaving. With regard to this latter point, unprotected steel was subject to chemical attack—often referred to as corrosion—from the constituents of the aerated concrete and from the autoclave atmosphere at the elevated temperatures occurring in the autoclave. The amount of such attack depended upon the raw materials used and the temperature and period of autoclaving, and so varied for different aerated concretes.

In one aerated concrete studied by Mr. Hobbs, the amount of such attack represented a negligible amount of loss of steel area, but was uniform and fairly reproducible, so that if it were considered worth while it could be corrected for any design. It simultaneously produced such excellent bonds that $\frac{3}{8}$ in. diameter steel bars broke in pull-out tests before the bond yielded. This attack did not progress after autoclaving, but neither did it protect the steel, so that normal corrosion could continue if suitable conditions existed.

With regard to normal corrosion, this only occurred particularly in an atmosphere containing sulphur dioxide and when the aerated concrete contained free water—that is, when it was in a condition where its thermal insulation properties were not being fully utilized. In other words, unintelligent use of these materials could lead to risks of corrosion if manufacturers did not protect their steel. That they did so, therefore, meant that the structural aerated concrete was proof even against misuse, and it was in this context that these materials should be viewed.

To support this statement, Mr. Hobbs mentioned a tour of Swedish and Continental sites where reinforced aerated concrete units were used. Many cases of misuse were seen—including careless damage to slabs and steel cutting and the exposure of bare steel surfaces by cutting—but no cases of failure, nor even of rust staining could be found.

It might be argued that better results would be obtained if advantage were taken of the high potential bond strengths of unprotected steel and the structural engineer and contractor were trusted to make intelligent use of the product. Such a view could only prevail after more experience of their use in this country.

Mr. G. H. NEWTON expressed surprise that the results of creep tests were plotted on the axis factors used in Figure 13. The use of ratio such as increase in deflexion over initial elastic deflexion was a very difficult one to apply for comparative figures depending as it did on the time of reading, rate of loading and type of load used.

The initial rates of creep were high and the point of maximum static deflexion hard to determine. He suggested that for comparative plotting a scale beginning 24 hours after loading, or one based upon the span of deflexion ratio, would be better.

Results based upon a series of tests on aerated concrete would seem to show that the curves in Fig. 13 should be reversed. As with a normal dense concrete the drier the atmosphere, and hence the test specimen, the greater was the creep. This agreed with the results shown briefly in Table 2.

The test series consisted of 20 ft. beams $9\frac{1}{2}$ in. deep with 0·5 per cent steel, (A, B, D,) and 11 ft. 3 in. beams 6 in. deep with 0·33 per cent steel (C, E,). Two tests each lasting 160 days were carried out, in the following manner :

1. Indoors : Beams A, B and C.
2. Outside : Beams B, C, D, E. Beam A was tested again indoors as a control specimen. Beam D was severely damaged early in the test, and the results were therefore discarded.

Table 2 results were based upon beams C and E. In Test 1 the beams A and B gave almost identical results, and a time deflexion curve of the same form and slope as beam C.

Test 2. The beams B, C, and E all gave curves of the same form as those in Test 1, but of flatter slope, but the control beam gave a curve which was in fact a continuation of its curve in Test 1.

The critical factor was the humidity, measured from a wet and dry bulb thermometer, the deflexion increasing as the humidity decreased. A very approximate variation would be 0·015 in. per 10 grains of moisture per lb. of dry air, the overall variation being about 60 grains throughout the test. These figures were taken from one of the 20 ft. beams.

This rate of variation remained approximately constant for the duration of the inside tests. When tested outside, however, these variations died away, presumably as the beam reached a saturation equilibrium due to frequent periods of wet weather.

**TABLE No. 2.**

$$\text{Ratio} = \frac{\text{increase in deflexion due to maintained load}}{\text{initial elastic deflexion due to load}}$$

| *Days of test* | *Indoors Beam C.* | *Outside Beam E.* |
|---|---|---|
| 50 | ·45 | ·30 |
| 100 | ·63 | ·37 |
| 150 | ·77 | ·38 |

*Effects of Welded Cross Bars*

Mr. Newton stated that, having conducted a considerable number of tests on the effect of welded cross links in reinforced aerated concrete beams, he did not agree that the number had little effect upon performance as stated in the Paper. It would seem that though an excess number of links did not materially affect the failure load it did have considerable effect upon the working load deflexion and the point at which cracking occurred.

Mr. J. BUEKETT commented that overseas tests and experience of fires in buildings had indicated that the fire resistance of aerated concrete was very good.

The Fire Research Station was carrying out a series of tests to B.S.476 and the results to date were as follows :-

5 in. standard roof slab, finished with three layer bitumen felt, soffit untreated—2 hour rating.

$2\frac{1}{2}$ in. non-loadbearing block wall, not plastered—2 hour rating.

4 in. loadbearing block wall (1220 lb/ft.) not plastered —2 hour rating.

Mr. Kinniburgh and other speakers had referred to compressive strength tests being carried out on saturated surface dry specimens. However, as aerated concrete was not recommended for use below D.P.C. would it not be more realistic to test specimens with a lower, but controlled moisture content? A precedent existed in B.S.373 : 1957 — Methods of Testing Small Clear Specimens of Timber, where the drying conditions were 20 ± 3° C. and 65 ± 2 per cent relative humidity. In the new Swedish Standard for Lightweight Cellular Concrete specimens were dried at 70° C. until the moisture content was 10 ± 2 per cent by weight and then stored at room temperature for 24 hours before testing. Also in the German standards DIN 4165 and DIN 4223 which dealt with aerated concrete specimens were air dried to a moisture content of 3-10 per cent by volume before testing.

He referred to the authors' statement on page 5 that it was undesirable that aerated concrete should become damp. A large number of problems would be solved if no building materials were allowed to become damp after manufacture. However, the matter should be considered in relation to practice and it would be fair to say that in common with other building materials aerated concrete should be kept as dry as possible during storage and use.

Whilst the thermal insulation was impaired by a high moisture content the same applied to all other materials. Frost damage was not a danger except when the cell structure was filled with water.

Mr. Buekett then referred to the question of resistance rain penetration. Vertical wall slabs of aerated concrete 6 in. thick, treated with paint and two solid aerated concrete block walls 8¾ in. thick rendered with 1 : 4 cement-sand and 1 : 2 : 15 cement-lime-sand mixes respectively had been tested at the Building Research Station. They all satisfactorily withstood the artificial rain test, no penetration of water occurring after spraying at a controlled rate for 6 hours.

The slides shown by Mr. Short during the introduction indicated that Fig. 10 only showed a portion of the Beckton exposure site. The flexural members shown in Figure 10 contained reinforcement protected with rubber latex-cement mix and were exposed under stress whereas the other protective systems were apparently tested by exposure of bars embedded in prisms of aerated concrete. The fact that no corrosion occurred on the rubber latex-cement protected steel despite the more severe conditions of test surely justified inclusion in Fig. 11 where its behaviour should be represented by a line coincident with the abcissa.

He thought that confusion might result from the statements on pages 2 and 11 that reinforcement was in the form of cages. The majority of manufacturers used mats consisting only of longitudinal and transverse bars welded together. However in some countries aerated concrete lintels were produced and these were reinforced with welded cages.

On page 12 the authors referred to the use of cement mortar screeds " to improve lateral interaction and the stiffness and strength of slabs." As far as this product was concerned, screeds were only used on floor slabs to provide protection where a thin floor covering such as linoleum was used. In the case of roof slabs, screeds were not used except where falls could not be provided by the supporting structure.

Mr. L. A. ASHTON wrote that from the fire protection point of view, aerated concrete had valuable properties. Like dense concrete, it was not combustible, it did not burn or add fuel to a fire, in spite of the fears expressed by a writer in a recent article on Structural Fire Protection about the presence of hydrogen in the pores of aerated concrete.

On the structural side the Fire Research Station had made a number of fire resistance tests, as specified in B.S. 476 : Part 1, on the products of several manufacturers. No planned series of tests had yet been made, but sufficient information had been obtained from the sponsored tests to enable them to make some general statements which showed that aerated concrete in some forms had advantages over more traditional materials. Their experience was mainly with walls of blocks, and with a thickness of 4 in. a fire resistance of four hours could be obtained. This could be compared with a fire resistance of two hours given by a wall of clay bricks 4½ in. thick. It was noticeable that exposure to high temperatures reaching to as much as 1200° C. caused little thermal movement, and therefore, in general, block walls appreared to have less deformation under given conditions of restraint than brick walls.

The considerations in mind in carrying out those tests had been the ability of a wall to act as a fire barrier, and at the same time fulfil its normal functions. They had not therefore been concerned with the condition of a wall after a fire, and there had been no question of dealing with the aspect of repairability or reinstatement.

Dr. F. W. GIFFORD (Member), in a written contribution, thanked the authors for a most interesting paper. He referred to the suggestion that the low density of aerated concrete led to substantial reduction in the dead load of buildings. He did not agree with this. Where dead load was a concern no one would use a solid slab for floors, and surely many of the hollow box, trough or pre-stressed joist type of floors would produce a lighter overall construction. For roofs particularly of long span where weight was most important, he suggested that an insulated hollow asbestos or metal decking would show appreciable weight saving over aerated concrete.

The material seemed admirable for inner skins of cavity construction, particularly where the inner skin was load bearing. Information had been given on "$k$" values. Had any long-term tests been carried out on walls such as a 4½ in. outer brick skin 2 in. cavity and 4 in. inner lightweight concrete skin, to compare a calculated $U$-value with test results.

In connexion with the use of lightweight aggregate as an insulating roof material, in view of the troubles which had occurred with this type of construction, he asked if the authors would like to comment on the desirability or otherwise of an efficient vapour barrier on the undersurface, to avoid condensation in the roof.

With reference to the 'shadow effect,' had any attempt been made to eliminate this, possibly by some very light vibration?

In connexion with the test of destruction on beams of Swedish make at the Building Research Station, failure occurred at about four times the total design load. Compared with normal reinforced concrete design, this appeared to be high, and he asked if the authors would please give details of the loading, reinforcement, assumed strength etc., and comment on this.

In answer to Dr. F. W. Gifford the authors state that long term tests on the $U$ value of various types of wall construction, including the one mentioned by him, are in progress at the Building Research Station.

With regard to the inclusion of a vapour barrier on the underside of roof-slabs made with aerated concrete, in normal atmospheric conditions inside buildings this is not necessary. Where the atmospheric humidity is high, e.g. in textile factories, a vapour barrier on the underside would seem desirable.

**Reference**

1. B.S.874 : 1956. "Definition of Heat Insulating Terms and Methods of Determining Thermal Conductivity."

2. Pratt, A. W., and Ball, J. M. E. (1956). *Inst. Heat and Vent. Eng. Jnl.* 24 (Aug.) 201-226.

# Book Reviews

**Hyperstatic Structures: An Introduction to the Theory of Statically Indeterminate Structures**—Volume II, Containing Worked Examples for Solution, by J. A. L. Matheson and A. J. Francis. (London : Butterworth Scientific Publications, 1960) 9¾ in. × 6¼ in., 282 plus xi pp. 60s.

This book of problems in structural analysis is a companion to Volume I which dealt with the theory. It follows the same format and thus serves to reinforce the impact of the earlier work. Many of the reviewer's previous comments (see *The Structural Engineer*, June, 1960) are again relevant, particularly with regard to the excellent production, the useful additional chapters by Drs. N. W. Murray and R. K. Livesley and the academic purpose and achievement.

In Volume I the senior author explained many of the numerous methods of structural analysis as developments from a few really basic theorems. This is an admirable approach but it is not, unfortunately, much help in guiding students in the art of selecting the most appropriate method for any particular problem. For the simple types of structure encountered in degree questions several analytical procedures may be equally practicable—a real difficulty is deciding which to use. Experience is a useful guide and the reader of Volume II has literally hundreds of problems to practise on. However, if he manages to read half the examples and tackle a quarter of the problems he should be very well prepared for most examinations in the theory of structures at degree level.

One of the most attractive features of both volumes is the easy manner in which the order of statical indeterminacy of different types of structure is considered. But, rather surprisingly, there is no mention in this second volume of the approximate methods of analysis which were explained so well in the first book. The examples on the classical methods of structural analysis, on deflexions and influence lines are all very well explained and the problems are nicely selected. The chapters on frames with rigid joints and arches are adequate but very definitely limited to degree level, with no mention of the powerful method of automatic sway correction or the stiffness factors approach to interconnected arches. The final chapters on the stability of struts and frameworks and on matrix methods are very topical but are somewhat inconsequential and short, respectively.

A possible criticism about the dangers of problem solving is countered by the authors in the preface by a rather irrelevant distinction—in this case—between basic science and creative art in structural engineering. For it really is apparent that the work is directed at the degree examination without much concern for the requirements of the real world outside the university. Many of the methods expounded would be quite inadequate for more complex structures, but the authors give little guidance on further developments and possibilities. The creative structural engineer might well expect a competent analysis of his designs and the problem solver—at this elementary level—would be of little assistance. However, these two volumes are described only as an introduction to the theory of statically indeterminate structures. They are very thorough but in an intense and limited way.

This work should very definitely—imperatively—be acquired by all engineering libraries, especially those serving the needs of our growing undergraduate population.

E. L.

**Building With Steel**, by D. A. Halperin. (London : The Technical Press Ltd., 1960) 10 in. × 7 in., 254 pp. 52s. 6d.

This book is based primarily on several courses taught by the author at the University of Florida, and is somewhat similar in content to that contained in brochures and handbooks published by the British Steelwork Association.

The subject matter ranges from a simple grillage to rigid frame design but unfortunately, being an American book, the treatment and standard of the subject matter renders it unsuitable as a textbook for the Structural Courses existing at present in this country.

Students of architecture, building and civil engineering would undoubtedly benefit from the detailed explanation, worked examples and photographs in this book on steelwork construction.

One or two of the detailed sketches will be criticized by designer-detailers, particularly the plate girder web splice. Probably the author intended them only to illustrate points in design and not as working details.

Students and others interested in welded structures may be shocked by the author's statement in cold print that welding, however, is not a perfect method of joining members and plates, etc. This statement is not intended to be a condemnation of welded work ; it is simply the author's method of passing on a word of warning to students of the difficulties that may still arise in this form of construction. Beams and column sections, Specification and Code of Practice are of course American standards.

C. S. B.

# Institution Notices and Proceedings

## FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

*Thursday, 9th November*, 1961

Joint Meeting with the Institution of Royal Engineers at 6 p.m., "The Development of Engineer Equipment for the Army," by Brigadier H. A. T. Jarrett-Kerr, O.B.E.

Advance copies of this paper may be obtained on application to the Secretary of the Institution.

*Thursday, 23rd November*, 1961

Ordinary General Meeting for the election of members at 5.55 p.m. This meeting, which is open only to corporate members of the Institution, will be followed by an Ordinary Meeting at 6 p.m., when a paper on "Services and Air Conditioning for Tall Buildings" will be given by Mr. J. R. Kell, M.I.Mech.E., P.P.I.H.V.E., F.Inst.F., M.Cons.E.

*Thursday, 14th December*, 1961

Ordinary General Meeting for the election of members at 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper on "The Chemical and Physical Effects of Aggressive Substances on Concrete" will be given by Dr. P. E. Halstead, B.Sc., F.R.I.C.

*Thursday, 11th January*, 1962

Ordinary Meeting, 6 p.m., "Structural Engineering Aspects of Vickers House, Millbank, London," by Mr. Colin Davies, B.Sc., A.M.I.Struct.E., A.M.I.C.E.

*Thursday, 25th January*, 1962

Ordinary General Meeting for the election of members at 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper entitled "An Investigation into the Cause of Damage to the Severn Railway Bridge" will be given by Mr. Peter Mason, B.Sc.(Hons.), M.I.Struct.E., M.I.C.E. (Member of Council).

Members wishing to bring guests to the Joint Meeting and the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

## MAITLAND TESTIMONIAL DINNER

A dinner, at which the Testimonial will be presented to Major Maitland, will be held at the Dorchester Hotel, W.1., on Thursday, 2nd November, at 7.00 for 7.30 p.m.

## EXAMINATIONS, JANUARY, 1962

The Examinations of the Institution will next be held in the United Kingdom and overseas on the 9th and 10th January, 1962 (Graduateship) and the 11th and 12th January, 1962 (Associate-Membership).

## HONOURS AWARD

In offering their sincere congratulations to the following member on the distinction conferred upon her, the Council feel that they are also expressing the good wishes of the Institution :—

*Order of the British Empire—C.B.E.*

Mrs. Florence Mary Taylor, L.R.I.B.A. (Associate).

## INTERNATIONAL FACTORY EQUIPMENT EXHIBITION

The organizers of the above Exhibition, which will be held at Earls Court, London, from 13th to 18th November, 1961, have sent the Institution complimentary tickets which may be obtained on application to the Secretary.

## EXAMINATIONS, JULY, 1961
## HOME AND OVERSEAS CENTRES

### PASS LIST

The Examinations of the Institution were held in July, 1961, at the usual centres in the United Kingdom and overseas at : Accra, Aligarh, Auckland, Barbados, Beirut, Bloemfontein, Bombay, Brisbane, Bulawayo, Calcutta, Cape Town, Christchurch (N.Z.), Colombo, Dacca (E. Pakistan), Dar-es-Salaam, Durban, Edmonton (Alberta), Hong Kong, Illinois, Jesselton, Johannesburg, Karachi, Khartoum, Kingston (Jamaica), Kuala Lumpur, Lagos, Lahore, Los Angeles, Malta, Melbourne, Mombasa, Montreal, Nairobi, Ndola, New York, Ottawa, Port Elizabeth, Pretoria, Rangoon, St. Louis, Salisbury (S. Rhodesia), Singapore, Sydney, Toronto, Trinidad, Tripoli, Wellington (N.Z.).

108 candidates took the Graduateship Examination (73 at home and 35 overseas). 305 candidates took Section 'A' of the Associate-Membership Examination (192 at home and 113 overseas). 427 candidates took Section 'B' of the Associate-Membership Examination (345 at home and 82 overseas), and 81 candidates took the special paper of Specifications, Quantities and Estimates under the old syllabus (66 at home and 15 overseas). Of these 22 passed the Graduateship Examination (15 at home and 7 overseas), 80 passed Section 'A' of the Associate-Membership Examination (55 at home and 25 overseas), 194 passed Section 'B' of the Associate-Membership Examination (162 at home and 32 overseas), 51 passed the Specifications, Quantities and Estimates paper (46 at home and 5 overseas).

The names of the successful candidates are :—

*Graduateship Examination*

AH-KEE, Roger
ALDRED, Andrew Charles
CHAKRAVERTY, Kamalakanta
DART, Alfred William
EDWARDS, Michael Roy
EXTON, John
FITZGERALD, Robert Henry
GILL, John Hargreaves
GLYNN, Christopher Patrick
LAKER, Francis Ellis
MEHTA, Ramanlal Makanji
MORLEY, Peter Stuart
NEWCOMBE, Peter Sturgeous
O'MAHONY, Timothy Joseph
SENGUPTA, Digendra Kumar
SHANMUGANATHAN, Chelliah
SILVA, Koralage H. A. D.
STANBRIDGE, Graham John
TAGGART, Robert

TEASELL, James Sinclair
VOLLANS, Keith
WILD, Brandon Thomas

*Associate-Membership Examination*
*(Section 'A')*

ADAVI, Hanumant Vishnutirth
ARTHUR, Roland Eric Brough
AZAM, Khalid
BANERJEE, Hari Har
BARWOOD, Richard Frederick
BEVAN, David Milton
BURROWS, Ronald Edward
CHAN, George Siu Cheung
CHAN, Kwok Cheung
CHAWLA, Manmohan Singh
CHOPRA, Ramesh Chanda
DODD, Bernard James Leslie
DUMMETT, Dennis Leslie
FREEMAN, Robert Charles Massie
GERRARD, John Roy
GIFFORD, Robert Charles
GODAVITARNE, Angulugahagamage Don Chandra
GOODWIN, David Laurence
GORADIA, Thakordas Andarji
GOSLING, Ernest Harvey
GUIN, Mihir Baran
GUPTE, Surendra Dattatray
GUY, Kenneth
HARPALANI, Dayal Sunderdas
HASWELL, John Frederick Stephen
HILL, Michael John
HODGKISS, Frank Hilton
HORLER, David Brian
HUTTMAN, Edilbert
JULIER, Joseph Martin
KUNDU, Ranajit Kumar
LEUNG Hoi Wah
LI Kin Fun
LILLEMOEN, Rolf Olaf
MANN, Geoffrey Edward
MASSAND, Nanik Pribhdas
MAZUMDAR, Satyandu Kumar
MHATRE, Chintaman Shanker
MORRIS, Clifford Hastings
MUKHOPADHYAY, Ashoke Kumar
NAVKAL, Anand Hari
NICHOLLS, Brian Leslie
PAL, Sudhindra Nath
PARIKH, Kirit Kantilal
PATEL, Manubhai Purshottam
PEMBERTON, Wilfred Volance
RAGHAVAN, Neman Echambadi Vijaya
RAMACHANIRAN, Kumbun Naranaiengar
REYNOLDS, Rodney Alan
ROY, Mihar Kumar
RZADKIEWICZ, Stanislaw
SACHANIA, Devendra Damodardas
SAMANT, Avinash Raghunath
SARKAR, Susanta
SCHROEDER, Bryan Payne
SHANMUKHANANDAM, Thiagaraja
SHER, Joseph Kar Kit
SIMPSON, John Melrose
SINHA ROY, Pijush Kumar
SKINNER, Donald Arthur James
SMART, David Charles
SMITH, Frank
SMITH, Peter Anthony
SMITH, Robert Walter James
SMITH, Stanley
SOLANKI, Chhaganlal Deuji
SPENCER, Norris
STECHLER, Arjeh
STEDMAN, Edward Rex
SUTHERLAND, Angus
SYMONDS, Raymond Charles William
TAMHANKAR, Mohan Gopal
TARI, Tarlochan Singh
THOMSON, Hugh Melville
TOLAT, Vipin Natwaral
VAIDYA, Chittarnnjan Dattatraya
VAN ESSEN, Albert
WEBB, Brian
WONG Chin Wah
WOOLGAR, Desmond Walter

*Associate-Membership Examination*
*(Section 'B')*

ABRAHAM, Albert Arthur
ASSIAMAH, Frederick Gottfried
BAGCHI, Matindra Nath
BAILEY, Peter John William
BALLENTYNE, Michael John
BANDYOPADHYAY, Amarendra Mohan
BARRATT, Gordon
BARRON, Gerald Percival
BELL, Colin Walter Herbert
BELL, Harold
BELLAMY, Carl Reginald
BERRY, John Graham
BHAMRA, Darshaw Singh
BICKNELL, Brian David
BISHOP, Ernest John
BLACK, Graeme
BLACKBURN, Michael Peter
BOTTOMLEY, Kenneth
BUKY, Karoly
CALLAGHAN, George Denis
CHANDRA, Tirtha Renu
CHANG TAI HON, Philip
CHEN CHIEN-HAI
CHEONG YI CHOON
CHOUDHURI, Manju Kumar
CLARKE, David James
COOPER, Raymond Barrie
CORNWELL, Dennis Frederick
COWLEY, Donald Holliday
DALVI, Avinash Prabhakar
DANDY, John
DAVIS, Charles James
DOWLING, Peter Alexander George
EDDISON, John Michael
EDWARDS, John Joseph
ENGINEER, Darius Manecksha
EYRE, David Alan
FENNER, Raymond Michael
FERRELLY, John Noel
FILMORE, Maurice Ernest Fuce
FREEMAN, Anthony John
FULLER, John Courtney
GARDNER, Richard Pringle McKay
GEE, Brian Lewis
GHOSH, Syamal Chandra
GIBBONS, Barrington
GILCHRIST, James
GOFF, Derrick Claude
GOODWIN, Harry
GRIMMOND, Roland Arthur James
GRIMSHAW, Rodney Erskine
GROENEWALD, Hermanus Bernhardus
GUY, Richard Watson
HAMILTON, Donald Winstanley
HARPER, Alfred George

HARRIS, James Orlando George
HARWOOD, George Alfred
HELM, Jack
HERBSTEIN, Moritz
HILL, John
HINES, Leslie William John
HINTON, Edward Frank
HOLLAND, Jack
HOOD, Anthony Paul
HORLER, Leslie
HULME, Terence William
HUNT, Anthony James
HUNTER, Kenneth
HURDLE, Anthony William

JENKINSON, Geoffrey Eric
JOHNSON, Colin Lionel
JONES, Henry James King

KAMAT, Bhalchandra
KELSHIKER, Atulchandra Balkrishna
KHALIQ, Mohd Abdul
KIRPALANI, Murli Bulchand
KUFUOR, Joseph Adjaya

LACK, William Brian
LAKHANI, Vraj Lal
LARK, Victor George
LEA, Norman Watson
LECK, George Yuill
LI PAI LIN
LINDSAY, Richard Herbert William
LLOYD, Kenneth James
LOZINSKI, Zygmunt Adam
LUGG, Harold Edward

MCLOUGHLIN, Kevin Joseph
MCPARTLAND, Michael John
MALCOLM, William Johnston
MANNING, Brian George
MARSHALL, Kenneth Arthur
MASSAND, Nanik Pribhdas
MATTOCKS, Ronald
MEANWELL, Ronald William
MENEHAN, Kevin John
MERRAN, Sidney
MIKA, Tadeusz
MILLAR, James Graham
MILLAR, Stuart Greig
MILLARD, Francis Edward
MITCHELL, Kenneth William
MORGAN, Robert Evan
MORGAN, Rotimi Modure
MOORE, Michael John
MORRIS, Anthony

NEKOO, Rustom Keikhusroo
NORFOLK, John Henry
NOWELL, Leonard Ewart

OBOSI, Louis Oranye Ezeudu
OLADEJI, Emmanuel Olaniyi
OMER, Hussein
OMOTOSO, Iyiola

PANG KIA CHOON
PARKINSON, Joseph Maurice
PARSONS, Patrick
PATEL, Kantilal Parbhabhi
PATRICK, Colin Desmond
PAUL, Peter Richard
PEACHEY, Donald Henry
PEEL, Roy Albert
PERCIVAL, John Adrian
PERRY, Brian Robert John
PIALL, George Henry Anthony
PORTER, John Ellis
PORTER, Robert George
POWELL, David Solomon
POWELL, John
PRINCE, George Arthur Joseph
PROBERT, Leslie Anthony
PRODROMOS, John Philip
PRYOR, Dennis Arthur

QADEER, Abdul
QUIGLEY, Peter
QUIN, Neil
QUINN, Felim

RABATHALY, Withlin Augustine
RAY, Syamal Kumar
REMEDIOS, Cleto Anthony
RICKETTS, Alfred Martin
RIDDICK, Alan Moir
RODRIQUES, Braz Maria Constantino de Assuncao
ROESSLER, Alfred Frederick
ROONEY, Dermot Francis
ROWE, John Albert
ROWE, Walter Ernest
RUTTER, Peter Arthur

SACKEY, Samuel Osam
SALAM, Abdus
SARDA, Shyamsunda
SATGUNASINGHAM, Kumarasingham
SCAMMELL, Ernest
SCHOLFIELD, James Clement
SCOBLING, Michael James Albert
SHEPPARD, Brian Richard
SIDDIQUI, Abdul Ali
SLOBOM, Geoffrey
SNOWDEN, George John
SOMES, Norman Frederick
SOWANDE, William Oluyinka
SPILLARD, Benjamin Charles
STANNARD, Robert Francis
STANYER, Anthony John
STAWARZ, Janusz Stanislaw
STEEDMAN, James Cyril
STEER, Peter John
STEVENS, Kenneth
STUBBS, Ian Rennie
STYLES, Ronald Walter
SZE, Peter

TAYLOR, Gordon Maurice
TAYLOR, Michael Anthony
THOMAS, Peter John
THOMPSON, Gordon Stanley
TOEG, Victor Muir
TREGEAR, Keith
TSUI KIN MAN

VECK, Griffith Alan
VIGAR, Peter George

WALKER, Geoffrey Charles
WALKER, Leonard
WALSH, Thomas
WATCHMAKER, Cyrus Sorabjee
WHITBY, Laurence Peter
WHITEHOUSE, David Edward
WILLIAMS, Brian Salathiel
WILLIAMS, David Powell Essex
WILSON, Graham
WOUNG, Clinton Rudyard

YOUNG, John Frederick
YOUNG, Reginald Alfred
YUAN TAO MING

ZEKARIA, Isaac Ezra
ZLOTOPOLSKY, Shlomo

*Associate-Membership Examination*

*Specifications, Quantities and Estimates*

(*Special Paper*)

AFFLECK, Michael John
BEDFORD, John Lewis
BROADHEAD, Geoffrey James
BROWN, William Patrick
BUDWORTH, George Joseph
CALLAGHAN, Brian Frank
CARRICK, John Leslie
CHAKRABORTY, Sudhanga Sekhar
CHASTON, Paul Bernard
COAPES, William Donald
COOPLAND, Jack
DEVONPORT, Derek Kenneth
DICKS, Derek
FORMAN, Donald
GAY, John Ernest
GLINIECKI, Leszek Feliks
HANNON, James David
HOLT, Eric John
JACK, William Sommerville
KAPKA, Jerzy
KROLIK, Stanislaw
LOZINSKI, Arthur Jerzy
McCRACKEN, William Weir
MacFARLANE, John
MAKIN, William Alan
MEEK, William Charles
MILLS, Henry George James
MORRISSEY, Frederick Walter
MURCH, Peter Walter
OBORSKI, Jerzy
PEARSON, John
PORTER, Alan George
REES, Michael Howell
REITH, Robert Davidson
ROY, Pradip Kumar
SAFIER, Armand Simon
SHALDERS, Michael Bloy
SMITH, Barrie George
SMITH, Victor Henry
STEPHEN, Raymond James
STOBBS, Alfred
TAN YORK HING
TAY KWANG SENG
TAYLOR, Peter Frank
THOMAS, Edwin Richard
TOFTS, Richard Nicholas Hailey
TOON, Maurice Naldrett
WHITE, Bryan John
WIESMEYER, Hans Leo
WONG LIM CHIN
YOUNG, Derek Leslie

## "THE BIRMINGHAM POST"

## STRUCTURAL ENGINEERING SUPPLEMENT

A twelve-page Structural Engineering Supplement is issued with *The Birmingham Post* published on Wednesday, 1st November.

Lt.-Colonel G. W. Kirkland (Past President) contributes an article on the Institution of Structural Engineers. Articles on modern applications of materials of construction and on the future of structural design are included, together with illustrations of some of the latest outstanding structural works in this country and abroad.

## ADDITIONS TO THE LIBRARY

*American Concrete Institute 55-Year Index*, 1905-1959. Detroit, Michigan, 1961. (Reference Library)

ANGERER, F. *Surface Structures in Building*, London, 1961.

*Architectural Institute of Japan, Structural Standards*, Tokyo, 1960.

BAKER, C. *A Guide to Technical Writing*, London, 1961.

*British Petroleum Equipment*, 1961/62 Edition, London, 1961. (Reference Library).

*British Standards Institution Annual Report*, 1960-61, London, 1961.

COMRIE, J. *Civil Engineering Reference Book*, 2nd Ed., 4 Vols., London, 1961.

*Earthquake Resistant Regulations of the World*, Tokyo, Japan, 1960 (Reference Library).

*The Engineering Index*, 1960. New York, 1961 (Reference Library).

HAMMOND, R. *Foundations and Soil Properties*, London, 1961. Presented by Mr. C. B. Brown.

JESSOP, H. and HARRIS, F. C. *Photoelasticity. Principles and Methods*, New York, 1960 (Republication of 1st Edition).

LISBORG, NIELS. *Principles of Structural Design*, London, 1961. Presented by Mr. J. McHardy Young.

MILLS, J. A. *A Modern Outline of Library Classification*. London, 1960 (Reference Library).

PADUART, A. *Introduction au calcul et à l'exécution des voiles minces en béton armé*, Paris, 1961. Presented by Mr. Leslie Turner.

RYDER, G. H. *Strength of Materials*, 3rd Edition, London, 1961.

SHANLEY, F. R. *Weight-Strength Analysis of Aircraft Structures*, 2nd Edition, New York, 1960.

SHEPHERD, G., Editor. *The Insulation Handbook*, London, 1961.

SOWERS, G. B. and SOWERS, G. F. *Introductory Soil Mechanics and Foundations*, 2nd Edition, New York, 1961.

STAMPF, W. *Der durchlaufende Bogenträger auf elastischen Stützen mit und ohne Versteifungsträger*, Berlin, 1960.

THOM, A. and APELT, C. J. *Field Computations in Engineering and Physics*, London, 1961. Presented by Mr. W. T. F. Austin.

THOMAS, W. N. *Surveying*, 5th Edition, London, 1961.

URQUHART, L. C., O'ROURKE, C. E. and WINTER, G. *Design of Concrete Structures*, London, 1958. Presented by Mr. A. C. Clarke.

*2nd World Conference on Earthquake Engineering Proceedings*, 1960. 3 Vols., Tokyo, 1960.

*World List of Abbreviations of Scientific, Technological and Commercial Organisations*, London, 1960. (Reference Library).

ZIGNOLI, V. *Le chantier de batiment et de travaux publics*, Paris, 1961. Presented by Mr. P. J. Gerard.

## Branch Notices

### LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged:—

*Monday, 13th November*, 1961

Joint meeting with the Manchester Society of Architects: "Architectural Misconceptions of Engineering," by Mr. A. J. Harris, B.Sc., M.I.Struct.E., M.I.C.E.

*Wednesday, 6th December*, 1961

"The Plastic Design of Steel Framed Structures," by Professor M. R. Horne, M.A., Sc.D., Ph.D., A.M.I.C.E.

*Thursday, 18th January, 1962*

Junior Members' Evening at the Royal Technical College, Salford.

*Wednesday, 31st January, 1962*

"The Economic Design of Shed Type Buildings, with Special Reference to the Use of the Plastic Theory," by Mr. S. Howell, M.I.Struct.E., at the Technical College, Bolton.

Unless stated otherwise, meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m., preceded by light refreshments.

MERSEYSIDE PANEL

*Monday, 20th November, 1961*

"Economics of Framed Structures," by Mr. L. R. Creasy, B.Sc., M.I.Struct.E., M.I.C.E.

*Wednesday, 13th December, 1961*

"The Construction of a Large Covered Reservoir," by Mr. J. W. Baron, M.I.Struct.E., at the College of Building, Clarence Street, Liverpool.

*Tuesday, 16th January, 1962*

"Recent Trends and Developments in Three-Dimensional Frameworks," by Dr. Z. S. Makowski, Dipl.Ing., D.I.C.

Meetings will commence at 6.30 p.m., preceded by light refreshments, and will be held, unless stated otherwise, at Liverpool University, in the New Civil Engineering Building, Brownlow Hill.

*Joint Hon. Secretaries*: W. S. Watts, M.I.Struct.E., A.M.I.C.E., 11, Newchurch Lane, Culcheth, Nr. Warrington, Lancs., and M. D. Woods, A.M.I.Struct.E., 8, Dennison Road, Cheadle Hulme, Cheshire.

## MIDLAND COUNTIES BRANCH

The following meetings have been arranged :—

*Friday, 1st December, 1961*

"The Structural Design of a new Store for Rackhams (Harrods) Ltd., in Birmingham," by Mr. F. G. Coffin, A.M.I.Struct.E., and Mr. J. N. Martin, A.M.I.Struct.E., A.M.I.C.E.

*Tuesday, 5th December, 1961*

Joint Meeting with the East Midlands Local Association of the Institution of Civil Engineers: "Vibration Problems in Relation to Foundation Design and Construction," by Mr. J. H. A. Crockett, B.Sc.(Eng.), A.M.I.Struct.E., A.M.I.C.E., at the East Midlands Electricity Board Demonstration Theatre, Irongate, Derby, at 6.15 p.m., preceded by refreshments from 5.30 p.m.

*Tuesday, 30th January, 1962*

Joint Meeting with the Warwickshire, Worcestershire and South Staffordshire Branch of the Royal Institution of Chartered Surveyors: "Have Quantity Surveyors and Structural Engineers any Common Interests?" by Mr. I. F. Barrell, F.R.I.C.S.

Unless stated otherwise, meetings will be held in the Byng Kenrick Suite at the College of Advanced Technology, Gosta Green, Birmingham, at 6.30 p.m., preceded by tea from 5 to 5.45 p.m.

*Hon. Secretary*: A. N. Jones, B.Sc.(Eng.), A.M.I.Struct.E., A.M.I.Mech.E., 4, Sunny Bank Road, Quinton, Birmingham, 32.

GRADUATES' AND STUDENTS' SECTION

The following meetings have been arranged :—

*Friday, 3rd November, 1961*

"Proposed Bridge over the English Channel," by Dr. A. R. Flint, B.Sc., reader in Structural Steelwork, Imperial College of Science and Technology.

*Wednesday, 15th November, 1961*

"Elevated Roadways," by Mr. G. B. Smedley, B.Sc.(Tech.), A.M.I.Struct.E., A.M.I.C.E., at the Electricity Demonstration Hall, Irongate, Derby, at 6.15 p.m., preceded by tea from 5.30 p.m.

*Friday, 8th December, 1961*

"Recent Research in Timber Engineering," by Mr. I. D. G. Lee, B.Sc.(Eng.).

*Friday, 5th January, 1962*

"Elevated Roadways," by Mr. G. B. Smedley, B.Sc.(Tech.), A.M.I.Struct.E., A.M.I.C.E.

Unless stated otherwise, meetings will be held at the Engineering Centre, Birmingham, and will commence at 6.30 p.m., preceded by tea from 6 p.m.

*Hon. Secretary*: R. J. Birch, B.Sc. (Graduate), 54, Quinton Lane, Birmingham, 32.

## NORTHERN COUNTIES BRANCH

The following meetings have been arranged :—

*Wednesday, 1st November, 1961*

At Newcastle. "The Volta Bridge," by Mr. C. R. Blackwell, B.Sc.

*Tuesday, 7th November, 1961*

At King's College, Newcastle. "What is Structural Engineering?" by Mr. P. D. Newton, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E.

*Tuesday, 21st November, 1961*

At Middlesbrough. Joint Meeting with the Tees-side Branch of the Northern Architectural Association: "Transport in Urban Areas," by Lt.-Colonel C. D. Buchanan, B.Sc.(Eng.), A.C.G.I., A.R.I.B.A., A.M.I.C.E., A.M.T.P.L.

*Tuesday, 28th November, 1961*

At Sunderland Technical College. "Reinforced Concrete Bridges," by Mr. L. Dobson, M.I.Struct.E., (Branch Chairman).

*Tuesday, 5th December, 1961*

At Middlesbrough. "The Runcorn-Widnes Bridge," by Mr. J. K. Anderson, M.A., M.I.C.E.

*Wednesday, 6th December, 1961*

At Newcastle. "Some New Developments and Applications of Prestressed Concrete," by Mr. H. Kaylor, B.Sc.(Tech.), M.I.Struct.E., M.I.C.E.

*Wednesday, 10th January, 1962*

Joint Meeting with the Tees-side Branch of the Northern Counties Association of the Institution of Civil Engineers: "Engineering Support to the Christmas Island Nuclear Tests of 1958," by Brigadier R. B. Muir, R.E., C.B.E., B.Sc., M.I.Struct.E., M.I.C.E., A.M.I.Mech.E., A.M.I.E.E.

*Tuesday, 30th January, 1962*

At Sunderland Technical College. "Concrete—its Materials and Making," by Mr. W. J. Henderson, M.I.C.E.

Meetings will commence at 6.30 p.m., preceded by buffet tea at 6 p.m. Unless stated otherwise, meetings in Newcastle will be held at the Neville Hall, and those in Middlesbrough at the Cleveland Scientific and Technical Institution.

*Hon. Secretary*: P. D. Newton, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., 6, Cornfield Road, Linthorpe, Middlesbrough, Yorks.

## NORTHERN IRELAND BRANCH

The following meetings have been arranged :—

*Tuesday, 5th December*, 1961

"Model Methods," by Professor S. R. Sparkes, M.Sc., Ph.D., M.I.Struct.E., M.I.C.E.

*Tuesday, 9th January*, 1962

"Design and Construction of a Shell Roof," by Mr. S. O. Morton, B.Sc., M.I.Struct.E., M.I.C.E.

Both meetings will be held in the David Keir Building, Civil Engineering Department, Queen's University, Belfast, and will commence at 6.30 p.m., preceded by tea from 5.45. p.m.

*Hon. Secretary*: L. Clements, A.M.I.Struct.E. A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast.

## SCOTTISH BRANCH

The following meetings have been arranged :—

*Wednesday, 15th November*, 1961

Joint Meeting with the West of Scotland Branch of the Institute of Welding : "Who Teaches the Science of Welding?" by Dr. J. Orr, B.Sc., M.I.Mech.E., M.I.E.S. (Light refreshments at 6.30 p.m. for 7 p.m.)

*Tuesday, 5th December*, 1961

"Crane Erection Problems," by Mr. W. H. Arch, B.Sc., A.M.I.C.E.

*Friday, 15th December*, 1961

Joint Meeting with the Glasgow and West of Scotland Association of the Institution of Civil Engineers : "Cable Spinning on the Forth Road Bridge," by Mr. H. Shirley Smith, O.B.E., B.Sc., M.I.C.E.

*Monday, 22nd January*, 1962

"The 300 ft. Span R.C. Arch Bridge at Howford, Ayrshire," by Mr. W. A. Fairhurst, C.B.E., M.I.Struct.E.

Unless stated otherwise, meetings will be held in the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, and will commence at 7 p.m.

### EDINBURGH SECTION

*Wednesday, 1st November*, 1961

Joint Meeting with the Edinburgh and East of Scotland Association of the Institution of Civil Engineers, at the North British Station Hotel, Edinburgh, at 6 p.m. : "Cable Spinning on the Forth Road Bridge," by Mr. H. Shirley Smith, O.B.E., B.Sc., M.I.C.E.

*Tuesday, 28th November*, 1961

Joint Meeting with the Edinburgh and East of Scotland Association of the Institution of Civil Engineers at the Heriot-Watt College, Edinburgh, at 6 p.m., "Piling," by Mr. W. G. N. Geddes, B.Sc., M.I.Struct.E.: M.I.C.E.

*Tuesday, 16th January*, 1961

"Structural Application of Tubes and Rectangular Hollow Sections," by Mr. G. B. Godfrey, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., (Associate-Member of Council).

*Hon. Secretary*: W. Shearer Smith, M.I.Struct.E., A.M.I.C.E., c/o The Royal College of Science and Technology, George Street, Glasgow, C.1.

## SOUTH AFRICA BRANCH

*Hon. Secretary*: E. B. Kretzschmar, A.M.I.Struct.E., P.O. Box 3306, Johannesburg, South Africa.
*Natal Section Hon. Secretary*: E. G. Bennett, A.M.I.Struct.E., P.O. Box 932, Durban.
*Cape Section Hon. Secretary*: R. F. Norris, A.M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

## SOUTHERN BRANCH

The following meetings have been arranged :—

*Friday, 10th November*, 1961

The Chairman's Address, by Mr. J. R. Lowe, B.Sc., M.I.Struct.E., A.M.I.C.E.

*Friday, 1st December*, 1961

"Instability of Thin-Walled Members," by Dr. P. S. Bulson, B.Sc., A.M.I.Struct.E., A.M.I.Mech.E.

*Friday, 26th January*, 1962

"Swedish Practice in the Construction of Multi-Storey Reinforced Concrete Flats," by Mr. H. E. Lewis, M.Sc., D.I.C., and Mr. G. S. Rendall.

The meetings will be held in the Main Lecture Theatre, Lanchester Building, University of Southampton, and will commence at 6.30 p.m., preceded by tea in the Refectory (West Site) from 6 p.m.

*Hon. Secretary*: A. P. K. Tate, B.Sc.(Eng.), Ph.D., A.M.I.Struct.E., Department of Civil Engineering, The University, Southampton.

## WALES AND MONMOUTHSHIRE BRANCH

The following meetings have been arranged :—

*Wednesday, 1st November*, 1961

At Swansea. Chairman's Address, by Mr. E. Hughes, M.I.Struct.E.

*Monday, 4th December*, 1961

At Cardiff. "Structural Steelwork at Spencer Works," by Mr. A. V. Hooker, M.I.Struct.E., M.I.C.E. (Past Chairman) and Mr. C. J. E. Morris, M.A., A.M.I.C.E.

*Friday, 15th December*, 1961

At Swansea University. Joint Meeting with the South Wales and Monmouthshire Branch of the Institution of Civil Engineers : "The Design of Reinforced Concrete through the Use of Plastic Models," by Mr. B. W. Preece, B.Sc.

*Wednesday, 31st January*, 1962

At Swansea. Joint Meeting with the South Wales Institute of Architects and the Reinforced Concrete Association : "Application of the Pretensioned Plate Technique," by Mr. F. Adler, B.Sc.(Eng.), A.M.I.Struct.E.

Unless stated otherwise, meetings in Cardiff will be held at the South Wales Institute of Engineers, Park Place, and those in Swansea at the Mackworth Hotel, and will commence at 6.30 p.m.

*Hon. Secretary*: W. D. Hollyman, A.M.I.Struct.E., 41, Greenfield Avene, Dinas Powis, Glamorgan

## WESTERN COUNTIES BRANCH

The following meetings have been arranged :—

*Thursday, 9th November*, 1961

Joint Meeting with the South Western Association of the Institution of Civil Engineers : " Engineer Support to the Christmas Island Nuclear Tests of 1958," by Brigadier R. B.Muir, R.E., C.B.E., B. Sc., M.I.Struct.E., M.I.C.E., A.M.I.Mech.E., A.M.I.E.E.

*Friday, 1st December*, 1961

Special Meeting to which kindred professional and technical bodies will be invited : " Long Span Suspension Bridges with reference to the Severn Bridge," by Mr. M. F. Parsons, B.Sc., A.M.I.C.E.

*Friday, 5th January*, 1962

" A Mobile Tower for Servicing Rockets," by Mr. F. K. Fennell, A.M.I.Struct.E.

Meetings will be held at Queen's Building, University Walk, Bristol, the November and January ones in the Small Lecture Theatre, the December one in the Large Lecture Theatre. They will commence at 6 p.m. and will be preceded by a light tea at 5.30 p.m.

*Hon. Secretary* : M. S. G. Cullimore, B.Sc., Ph.D., A.M.I.Struct.E., Queen's Building, University Walk, Bristol, 8.

## YORKSHIRE BRANCH

The following meetings have been arranged :—

*Wednesday, 15th November*, 1961

In the Department of Civil Engineering, The University, Woodhouse Lane, Leeds. " The Design of a Cantilever Stand for the Sheffield Wednesday Football Club," by Mr. H. C. Husband, B.Eng., M.I.Struct.E., M.I.C.E., M.I.Mech.E. (Vice-President), Mr. T. Holmshaw, M.I.Struct.E., and Mr. H. C. English, B.Eng., M.I.Struct.E., A.M.I.C.E.

*Wednesday, 29th November*, 1961

At Sheffield. " Air Conditioning and Services for Tall Buildings," by Mr. J. R. Kell, M.I.Mech.E., P.P.I.H.V.E., M.Inst.F., M.Cons.E.

*Wednesday, 13th December*, 1961

At Leeds. Joint Meeting with the Yorkshire Association of the Institution of Civil Engineers and the Yorkshire and Lincolnshire Branch of the Institution of Highway Engineers : " The Doncaster Motorway—Reflections in Retrospect," by Mr. S. Maynard Lovell, O.B.E., T.D., M.I.C.E., M.I.Mun.E.

*Wednesday, 17th January*, 1962

At Leeds. " The Chemical and Physical Effects of Aggressive Substances on Concrete," by Dr. P. E. Halstead, B.Sc., F.R.I.C.

Unless stated otherwise, meetings in Leeds will be held at the Metropole Hotel, King Street, and those in Sheffield at the Royal Victoria Hotel, and will commence at 6.30 p.m., preceded by buffet tea at 6.15 p.m.

*Hon. Secretary* : W. B. Stock, A.M.I.Struct.E., 34, Hobart Road, Dewsbury, Yorks.

## SECTION NOTICES

### AUCKLAND (NEW ZEALAND) SECTION

*Hon. Secretary* : A. Donald, B.Sc.(Hons.), A.M.I.Struct.E., 122, Matipo Road, Te Atatu, Auckland, New Zealand.

### EAST AFRICAN SECTION

*Hon. Secretary* : K. C. Davey, A.M.I.Struct.E., P.O. Box 30079, Nairobi, Kenya.

### NIGERIAN SECTION

*Hon. Secretary* : A. Brimer, M.I.Struct.E., Brimer, Andrews & Nachshen, Private Mail Bag 2295, Lagos, Nigeria.

### REPUBLIC OF IRELAND SECTION

*Hon. Secretary* : P. J. Carroll, M.E., A.M.I.Struct.E., A.M.I.C.E., A.M.I.C.E.I., 9, Laburnum Road, Clonskea, Dublin, Ireland.

### SINGAPORE AND FEDERATION OF MALAYA SECTION

*Hon. Secretary* : J. R. M. MacIntyre, A.M.I.Struct.E., c/o Redpath, Brown & Co. Ltd., P.O. Box 648, Singapore.

### SOUTH WESTERN COUNTIES SECTION

The following meetings have been arranged :—

*Friday, 3rd November*, 1961

The Chairman's Address, by Mr. J. D. Norfolk, M.I.Struct.E., M.I.C.E. M.I.Mun.E.

At the Grand Hotel, The Hoe, Plymouth, at 6.30 p.m.

*Friday, 8th December*, 1961

" Site Production and Placing of Concrete," by Mr. R. J. Tatt, A.M.I.C.E.

*Friday, 5th January*, 1962

Joint Meeting with the Institution of Civil Engineers : " Aluminium Structures with Particular Reference to Bridges," by Mr. R. M. Davis, B.Sc., A.M.I.C.E.

Unless stated otherwise, meetings will be held at the Duke of Cornwall Hotel, Plymouth, commencing at 6 p.m., preceded by tea at 5.30 p.m.

*Hon. Secretary* : C. J. Woodrow, J.P., M.I.Struct.E., " Elstow," Hartley Park Villas, Tavistock Road, Plymouth, Devon.